THE ENGINEERING RECORD

PUBLISHED WEEKLY BY THE

McGraw Publishing Company

James H. McGraw, Pres.; Curtis E. Whittlesey, Sec. and Treas.

MAIN OFFICES:

239 WEST 39TH STREET, NEW YORK.

BRANCH OFFICES:

CHICAGO: Old Colony Building.

PHILADELPHIA: Real Estate Trust Building.

CLEVELAND: Schofield Building.

SAN FRANCISCO: Atlas Building.

LONDON OFFICE: Hastings House, Norfolk St., Strand.

SUBSCRIPTION RATES.

United States, Cuba and Mexico.....$3.00 a year

Canada .....$4.50 a year

Foreign subscription.....$6.00 a year

25 shillings. 25 marks. 31 francs.

Foreign subscriptions may be sent to our London office.

NOTICE TO ADVERTISERS.

Changes in advertisements intended for a particular issue should reach the office of THE ENGINEERING RECORD on Friday of the previous week. New advertisements can be received up to noon of Wednesday of the week of issue.

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Entered at the New York Post-Office as Second Class mail matter.

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Of this issue of THE ENGINEERING RECORD 16,000 copies are printed. Total circulation for 1907 to date, 642,000 copies, an average of 14,591 copies per week.

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Cooling Tower Tests.

Although but a small percentage of power plants include a cooling tower in their equipment, the absence of a continuous and suitable supply of condensing water and high cost of fuel not infrequently combine to induce plant owners to install apparatus for the artificial cooling of the circulating water and the return of as much as possible of it to the condensers. In such plants it is quite as important to find out whether the cooling tower is operating efficiently as it is to run down wiring losses and minor leaks in steam pipes and traps, and the failure to keep cooling tower records on daily station log sheets may lead to considerable losses in the form of excessive coal or water consumption. Purchased water is decidedly worth saving in a large plant, and even a small station dependent upon a limited natural supply and forced to buy boiler or circulating water will run up quite a bill in the course of a year if the water is not economically handled. In one of the Boston elevated gas engine plants the cost of purchased water exceeded the cost of fuel prior to the securing of water by the company from a neighboring brook. The illustration simply indicates the importance of the water question, even under careful management.

The designs of cooling towers vary so widely, from the home-made apparatus often constructed by ingenious operating engineers to the carefully finished equipment of the manufacturing companies, that it is obvious the tests made in any given installation must be governed largely by local conditions. Certain fundamental data are required, however, in any comprehensive test which aims to show the fitness of a cooling tower outfit for its work. If time and facilities permit, the physical quantities collected and their resulting analysis can be made very extensive.

The temperature of the circulating water as it enters the condenser is the most important index of the performance of the cooling tower. Taken in relation to the temperature of the outside air, the supply temperature is of great interest as affected by the season of the year and the weather prevailing at the time. It ought to be clear to every operating engineer that the conditions must be known which may modify the action of a cooling tower installation if the best operating results are to be secured. Thus, in the jet condenser plant, the injection water and part of the condensation are mixed and pumped together through the cooling tower cycle. Here the make-up water required to replace the loss by evaporation in the cooling tower may come either from the hot well, or from a metered service, perhaps, in extreme cases. In figuring the quantity of circulating or injection water required to be passed through a cooling tower in a given run allowance must be made in a test of high accuracy for the assistance given by the engine exhaust. Fortunately for simplicity of testing, the cooling tower and the surface condenser plant afford a much easier equipment to study, for here the exhaust and the circulating water are, of course, never intentionally mingled.

A thorough test of the efficiency of a cooling tower will obtain the volume of air supplied by the fans, if the installation be of the blower type; the temperature of entering and departing air, and if possible its relative humidity, and the height of the barometer; the power consumption and speed of the fans, determined from kilowatt-hour records on the motors or indicator cards from the engines; the quantity of water passed through the condenser circulating system, and if feasible the amount of make-up water; and the load upon the engines or turbines together with the condenser vacuum maintained. There is room for much research in connection with the reduction of operating expenses through a diminished pumpage and decreased fan movement, and in many cases the study of the effect of different arrangements of spraying and scattering the water drops in the cooling tower tank itself will richly repay the engineer who takes the trouble to go into the subject. Ingenuity will be required to confine the physical quantities which are to be measured in most instances, and the determination of meter accuracy, pump slippage, anemometer errors, and the like call for first-class work. Small errors in temperature and humidity measurements carry heavy weight in the final results, and failure to estimate the amount of external water supplied in cases where the cooling tower tank is utilized for general drainage purposes leads to inaccurate conclusions. The power plant which can be operated more economically without a cooling tower than with one, because of cheap or free water, or low cost fuel is fortunate, because it thereby avoids an extra complication in equipment. When the conditions require special cooling outfits, their careful observation and occasional test are essential for the best results in the way of keeping costs low.

Hydraulic Developments at Low Head.

The Engineering Record has recently published descriptions of several power plants which are notable for the clever utilization on a fairly large scale of very moderate head. The water powers of the United States are of a very variable character. In the Rocky Mountains and westward are found, in the main, rapid streams which can be utilized at very high head with tolerable ease. Heads of four or five hundred feet are common and those of a thousand feet or more by no means rare. The engineering work of development in such cases is frequently very simple, residing mainly in the system of conduits necessary for a relatively small volume of water. The dam is often merely a deflecting wall to turn the stream into the sand boxes. A few such high heads are found in the lower Appalachian region and fewer still elsewhere. Throughout the Middle West, however, the water powers, relatively few in number, are almost all at low head, say from 40 ft. down, and their utilization is correspondingly troublesome, involving long dams and a vast amount of material to be handled. The Michigan plants described in this and the last two issues are of this character. The two upon the Muskegon River are notable not only for their construction but from the fact that in this region the highest point yet touched in transmission voltage, 72,000 volts, has been reached. The stream itself is possessed of some valuable properties not usually found in rivers fed from more mountainous regious. A relatively flat drainage area, fairly well wooded, gives the stream an extraordinarily steady run-off. The maximum flow recorded, at least in recent years, is only about 8½ times the recorded minimum. When one considers that in the Connecticut River, a typical Eastern stream, this ratio is nearly 100:1 the vast difference in conditions is obvious.

In consequence of the favorable flow conditions it was practicable in both the Muskegon plants considered to make free use of earth embankments with mere core walls of reinforced concrete for large sections of the dams, using concrete construction only for the waste gate portions. In case of the Croton development no inconsiderable part of the material was moved by hydraulic sluicing, a process quite out of the question on most streams, while in the Big Rapids development the earth was mainly handled by teams and scrapers and the core of the dam was merely a 10-in. reinforced concrete wall built over sheet steel piling. In each case the waste gate section was of concrete, and the water passes from the gates into a tumble bay and thence over a low concrete weir into the waste channel. Another common feature is the use of Tainter sector gates on the waste gate portion, thus giving complete control of the head over a considerable range of variation. This evolution of the flash-board idea seems singularly well fitted for its work and is readily applicable to many cases in which, particularly at times of low water, the head must be kept at the highest available point and must be dropped for self-preservation at times of flood. The normal head in each case is

about 40 ft. The third plant considered, that near Lyons, on the Grand River, has less favorable natural conditions, the drainage basin being of clayey soil and giving a quick run-off, with much larger variation of flow than on the Muskegon. Here the dam was almost wholly of reinforced concrete, also equipped to the end just noted with Tainter gates aggregating no less than 200 ft. in width. There is also, as at the Croton development, a spillway with a movable shutter. The head, however, is only 26 ft.

In each of the three plants, the usual trouble incident to low head was encountered, that a somewhat complicated wheel plant was necessary to give the requisite speed to the generators. It is open to question, indeed, whether too much was not sacrificed to a desire for a generator of large output. Four pairs of turbines, as in the Croton plant, united to their load by 110 ft. of 12-in. steel shafting, certainly strikes one as excessive duplication and does not favor, to put it mildly, great hydraulic efficiency. The Big Rapids plant has generating sets of more simple design and one might well hazard a guess that they will be more satisfactory in operation. The Lyons plant from its lower head has more excuse for extreme design, yet it seems hardly necessary to have installed four pairs of turbines, for the sake of driving 138 ft. of shafting and a single generator. Doubtless the generator cost was lowered, but will it pay in the long run as regards the entire plant? In none of these plants, fortunately, was there need of going to vertical shaft construction of which several examples have been recently seen. The vertical shaft does, indeed, enable one to keep the generating room above high water mark, but it is liable to cause extra cost for attendance on account of the step bearings. The plants here considered play an important part in the economy of railway and power development in southwestern Michigan, both in interurban railway work and in the ordinary work of electrical supply. The networks of which they form a part are rapidly growing in importance, and to the engineer are of peculiar interest on account of the extreme high voltage work which is being carried out. The completion of the 100,000 volt line from the Big Rapids plant will mark the beginning of a larger sphere for electric power transmission and will serve as a sort of trial horse for various immense projects elsewhere that require the highest voltage that can be made available.

Standardizing Power Station Records.

To a company operating several power plants in different parts of its territory, the importance of accurately comparing the performance of the various stations is unquestionable, if the best possible records in low power cost are its object. It seldom occurs, however, that the conditions in the different plants are alike in complete detail, even in cases where the plants are supplying power for the same kind of service. The installation of a number of plants rarely occurs at the same period with the same company, and differences in the design and arrangement of generating machinery are sure to creep in if the company takes advantage of the progress in the field of power equipment which is so striking a feature of modern mechanical engineering. Thus it may easily happen that a single street railway system will be supplied with exactly the same kind of power from a dozen different plants in which the individual machines run the gamut from the steam turbine to the vertical, marine type engine, and from the belted non-condensing auxiliary steam engine to the producer gas engine direct connected to its special generator. All this may occur in a single city, and when the range of plants operated by one central organization extends through different parts of a country, the problem of comparison becomes still more difficult.

Before the operating figures of scattered plants can be interpreted, a system of records must be standardized which will enable comparisons to be fairly made. Local conditions exert a profound influence upon the cost of power production, and a place must be provided for the setting forth of these, if just comparisons are to be made possible. Whether the records are to be made on a daily, weekly or monthly basis, the points in common between the different plants must form the basis of log sheet and record blanks from which comparisons are to be worked out. The greater the similarity in equipment, the more easily can the sheets be standardized. If the power generated in one plant is used for a single service and that in another for several kinds of application, it will be necessary to include a certain space on the form which can only be used by the station of varied duties, and which must be left blank by the plant to which the headings do not apply. To a narrow mind an unused space on a record blank looms large, but to the eye of discrimination and to the sense of proportion it becomes of slight importance whether all the items are alike in type, so long as the essential conditions of each case are presented.

In dealing with a number of plants under the same management two main objects are present: First, to compare the plants one with another in relative efficiency and general performance, and second, to employ as far as is practicable, the same blanks and forms in each. Unless one uses a sheet of mammoth proportions, it is scarcely possible to incorporate the details of the daily log on a single form for several stations, though sometimes a large sheet is of great advantage in comparing the fluctuations of a single very important item. Thus, a street railway company operating eleven plants found it helpful to plot on a single sheet the total load upon its stations between 5 and 6 p. m. each day in the year, and the resulting curve of maxima required a wall space about 7 ft. long for its proper display. Compared with the afternoon peak loads of the previous year plotted beneath, the curve gave a valuable hint of the motive power requirements long before they actually came to pass. The same company also used to advantage a single blank which showed the maximum momentary station load, and the average hourly load throughout the entire day, with the number of machines in circuit from hour to hour in each plant. Space was provided to show during each of the three operating shifts in each plant the numbers of the engines, generators, boilers, gas producers and condensing apparatus not available for service, with a brief designation of the coal quality.

On a general comparison sheet there are a large number of items which can be recorded, regardless of the character of the machinery in each station. Among these are the total hours each station was operated, the total fuel consumption, the total power output in kilowatt or horse-power hours, the fuel consumption per unit of total output, the quantity of oil, waste and water required, the maximum load, duration of interruptions, repairs made, special inspections, weather, temperature of outside air, barometer and average temperatures and steam pressures. Some of these items would clearly be encumbrances upon a sheet where hydro-electric plants are listed beside steam driven or gas stations, but even here the practice of leaving inapplicable spaces blank is better than the multiplication of separate station records. In general, a large number of hour to hour readings in different plants and of many quantities, cannot well be listed on a comparison sheet, but the averages, maxima, minima and totals can be, to great advantage. To list all the items which can be profitably included in a general comparison sheet would require the space of a small catalog, but the above outline shows how wide the range may be, especially if one goes into performances on the unit basis.

In the matter of standardizing the forms of log sheets to be used in daily operation in each of a group of plants, the main consideration is to provide enough columns under each class of unit to enable both the largest and the smallest station to use the same kind of sheet. Daily report blanks for single plants necessarily must conform more closely to the local conditions than summaries of the performance of whole stations. For this reason it may in some cases be desirable to establish one form of log for one type of plant, such as fuel-burning installations, and another for hydro-electric stations. Among the items which can be employed to advantage on a standard form of record are, the hourly load curve; the hourly operation, banking or reserving of boiler units; the hourly temperatures and pressures, continuity of prime mover and generator service; names of men on duty each shift; use or non-use of auxiliary apparatus from hour to hour; outputs per unit and per feeder, the latter optional on a separate record if highly complicated; emergency happenings, inspections, receipt of fuel, machinery and supplies; service interruptions, voltage readings, supplies on hand and apparatus crippled. The use of a standard size of sheet with uniform dimensions for all plants, clearly printed and well arranged in headings tends to facilitate comparisons no less than the inclusion of the proper items. It is not to be expected that record forms will remain unchanged from year to year, but when these changes occur, they should be made by issuing a new series of records for the whole group of plants instead of attempting to get along with both old and new forms at the same time.

Some Considerations in the Design of Elastic Arches.

The design of elastic arches or arch ribs as they were more frequently called in early engineering literature had not been the subject of much consideration prior to the introduction of reinforced concrete. The capacity to resist tension given to that material by steel reinforcement adapts it admirably to the design and construction of arches with the added excellence of a grace of outline and proportions scarcely attainable in ordinary masonry. The extension of the present application of reinforced concrete in the construction of arches of all practicable lengths of span makes it not only desirable but almost imperatively necessary to acquire a clear view especially of any doubtful points of design.

The theory of the inelastic arch considered as a series of blocks of unchanging form and perfect joints is one of the oldest analytic or graphical procedures in engineering, but the complete theory of the elastic arch has been considered only for a comparatively few years, in spite of the fact that Rankine set forth some excellent features of treatment in his original works. The full general scheme of treatment is now to be found in many authoritative works to which, as they are so well known, it is not necessary to make any special reference, but there are some considerations regarding rather the extent to which the treatment is to be carried than any detailed question of that treatment which are worthy of careful reflection.

The usual method of design conveying simply the application of the common theory of flexure involves the neglect of any change of form of the rib due to the effects of loading, as is constantly recognized. In spite of that recognition, however, it is an open question how far that

neglect is permissible. Obviously in comparatively long spans and small depths of rib the omission to give weight to the elastic distortion of the rib might mean a material error although it might rarely be a dangerous one. In short spans and under ordinary circumstances of design the recognition of this elastic deformation might properly be considered an unnecessary refinement, but there is a limit to which that neglect can be carried, although it may not be possible to make a definite assignment of that limit. This elastic deformation clearly results from both the bending of the rib and its shortening, due to direct compression, both of those influences leading to deflection. That deflection in turn changes the position of the closing line in the case of a continuous rib and modifies the bending moment correspondingly. Practically the same general condition results in the case of a rib with jointed ends, although the closing line is not changed in position. It is not a matter of any sensible difficulty to make the proper allowance for these elastic deflections. The difficulty arises rather in determining the conditions under which the necessary allowance should be made.

Another point of what may be termed important doubt arises in connection with a proper provision for the change of temperature which the material of an elastic arch may experience from one season to another. While probably the majority of engineers may accept a high estimate in range of temperature in this latitude there are others of extended experience in this class of work who believe that the subject of temperature allowance is much over-worked. It is clear that the mass of a reinforced concrete arch supporting a roadway platform above it with a body of water underneath cannot possibly be subjected to the same amount of temperature variation as an articulated steel structure. A range of 100° to 120° Fahr. is not unfrequently considered in connection with steel bridges, but there is little or no reason to believe that any such extreme range can take place in an arch. Indeed if the arch has much span and corresponding mass it would be more reasonable to assume that the extreme range may not be more than 20° to 30° from the mean. It requires but few computations to show that in an arch rib of comparatively small rise the assumed range of temperature variation may play a very important part in the computed stresses, and yet in some existing structures of this character where the atmospheric seasonal changes are great there appears no evidence of the corresponding intensities of stress. Where the rise of the rib is comparatively great these considerations become of much less importance although they are still material. There is still lacking a large amount of highly desirable data of this character.

These observations indicate some of the more important open questions in the design of elastic arches, although there are others, such as spandrel walls continuous with the supporting arches, which are frequently more or less troublesome to the designer. The construction of some long span elastic arches now in progress, as well as those already standing, when subjected to proper observation, could be made to supply much useful data of the kind indicated, and it is much to be desired that requisite observation should be made in the interest of this important field of engineering construction.

A Discussion of Steam Turbines.

At the recent Atlantic City convention of the American Street and Interurban Railway Engineering Association three papers on the steam turbine were presented by representatives of as many manufacturers, each covering different features of turbine use. As the power plants of traction companies have alone rivaled central stations as sources of information concerning steam turbine practice, it was but natural that these prime movers should receive special attention at the convention, and in the three papers some helpful indications of present tendencies in the use of turbines can be perceived. For example, Mr. St. John Chilton, of the Allis-Chalmers Co., recommends in one of the papers a steam pressure of about 150 lb. as being the most economical in the operation of turbines, stating that a greater saving may be effected by the use of a small amount of superheat than by increasing the initial pressure above that amount. He remarks that an increase in pressure to 175 lb. results in a gain of but 2 per cent in steam economy, an additional 3 per cent being gained in an increase to 200 lb., against which should be placed the increased cost of piping, boilers and possibly of the turbine itself. He brings out the point that a higher vacuum is not required with turbines than with reciprocating engines, but that the turbine can utilize high vacuum to better advantage. The difference in economy within the range between 6 and 3 in. absolute terminal pressure is approximately 5 per cent per inch, the rate of increase of economy proceeding at a greater ratio as the terminal pressure goes below 3 ins. The use of superheated steam increases the economy, but the increment of saving becomes smaller as the superheat is increased, the reduction in steam consumption with 50° F. superheat approximating 7 per cent., with 100° F. 10 per cent., and with 150° F. 12.5 per cent.

Another feature of turbine operation was brought out by Mr. A. H. Kruesi, of the General Electric Co., namely, the adaptability of the turbine to the loads that arise on interurban and heavy traction systems operating relatively few cars on infrequent headways. The test of a 9000-kw. turbine by the Commonwealth Electric Co., of Chicago, showed water rates of from 12.9 to 13.6 lb. per kw.-hour on loads ranging from about 50 to 150 per cent. of the rating. This the author mentions as representing the "highest attainment thus far reached in the generation of power from steam." He shows that steam at the pressure and superheat employed in three tests referred to and expanded to 1.5 ins. absolute terminal pressure would give an economy of 9.27 lb. water per kw.-hour in a theoretically perfect engine or turbine with a generator of unity efficiency, and that the turbine in these tests has atained an efficiency of 76.4 per cent. of that theoretically obtainable, which "indicates that we are approaching the practical limit of perfection in the production of power from steam." On the subject of pressure, vacuum and superheat, Mr. Kruesi's statements agree with those in Mr. Chilton's paper. In the matter of superheat the suggestion is made that much of the trouble which has attended the use of superheated steam is due to the want of elasticity in the parts affected, it being probable that water may exist under certain conditions with superheated steam, the resulting variations in temperature, due to the spraying of heated surfaces, being enormously increased thereby. Changes in design of pipe fittings, valves, boilers and superheaters to care for this factor are suggested in order to permit of higher degrees of superheat. Improvement in economy arising from better vacuum is mentioned as that most easily attained, and an improvement in condensing equipment the easiest manner in which to lighten the duty on the boilers.

A recent development in turbine power plant designs, exemplified in the station of the Fort Wayne & Wabash Valley Traction Co., was explained in a paper by Mr. J. R. Bibbins. The station handles a combined railway and lighting load, as is fairly common with companies of its character. The author shows the manner in which the lighting load makes up for the early morning deficiency in the railway load, the latter usually falling off in the evening as the lighting load increases, and although the two systems are independent as to generators and turbines, steam is supplied to meet the average load of both systems, resulting in a much more effective working of the boiler capacity. Relating to this subject of improvement of efficiency with betterment of the load factor, the author presents curves showing the effect of the load factor on operating costs under the conditions obtaining at Fort Wayne. These curves show that an increase in low load factors brings greater increase in efficiency than a corresponding increase in higher load factors.

The Fort Wayne station is of peculiar design, consisting of a two-story building with the generating machinery on the second floor over the boilers, allowing simple, short and direct steam piping, with continuous upward slope from boiler nozzles to turbine throttles and barometric jet condensers entirely below the exhaust outlets of the turbines. While the remaining features of the design are those commonly found in stations of approximately this capacity—7,000 kw.—yet there is an absence of engineering frills for securing the highest possible efficiency, this being compensated for by lower capital cost. This low first cost, as well as the small area of station per kilowatt capacity, are the two important features of this type of station as brought out by the paper. The general arrangement, that of turbines and generators on a second floor above the boilers, accomplishes the second—small ground area, while it aids materially in the first—low cost. The cost of the building is certainly low—10.97 per kilowatt, figuring the ultimate capacity of 8,500 kw. It is shown that with larger boiler units a more compact arrangement might be made, while it is quite possible that with a demand for stations of this type a boiler could be obtained giving a narrower battery. The arrangement, while an ideal one for steam piping requirements, is also conducive to low cost of piping, this charge being about $2.50 per kilowatt. Economizers were not considered necessary on account of the low cost of fuel. Mechanical stokers are used, both to provide forcing capacity and to reduce labor cost, the present saving in labor being estimated at about $16 per shift of twelve hours. Barometric jet condensers are used, the condenser head being suspended beneath the turbine. A vacuum of 26.5 to 27 in. at full load is maintained in warm weather, the cost of the condensing equipment being only about $2.50 per kilowatt, including pumps and piping. The turbines are of the Parsons type, part of the generators being 25 cycle and part 60 cycle, for the railway and lighting load, respectively. The exciters are direct connected to the turbines, and while adding 2.6 per cent to the cost of the main generating unit, represent a saving of 20 per cent. as compared to the cost of independent exciting units. The operating costs, considered strictly alone, are not especially low, but are expected to reduce with the better load factor which will be the result of contemplated extensions in the traction lines. The labor cost is fairly low, being 0.12 per cent. per kw.-hour at present. Taking into consideration, however, interest, taxes and depreciation, the total power cost, including these items, is quite low, being 0.79 per cent. per kw.-hour with the present load factor of 24 per cent. Curves are presented showing that with 33 per cent. load factor this total cost will be reduced to 0.57 per cent., and with a possible load factor of 50 per cent. to 0.41 per cent. per kw.-hour. This low total cost of course is possibly due to the very low cost of the completed power station, which is shown to be but $66.25 per kilowatt, exclusive of land. Interest and taxes are taken as 7 per cent., while a sinking fund of 4.2 per cent., equivalent to 6.43 per cent. depreciation, is allowed in figuring total cost of power.

HEAVY FOUNDATIONS FOR THE NEW STEEL WORKS AT GARY, IND.

The soil conditions at the site of the immense new steel works of the United States Steel Corporation at Gary, Ind., are such that comparatively little difficulty is experienced in securing perfecly stable foundations for the heavy structures and machines which are included in those works. The blast furnaces, the machinery and equipment and the ore-handling docks and storage piles for the works are being built, however, on a scale that has never been undertaken heretofore, with the result that foundations and footings of unusual magnitude are required. The site of the works is along the shore of the extreme southern end of Lake Michigan, where a stratum of fine, clean lake sand, from 30 to 60 ft. in depth, covers the surface. The original ground level was a succession of alternate sand dunes and hollows, parallel to the shore line of the lake, with an average height of about 20 ft. above the water level in the latter. Under this sand, at a depth of 30 ft. below the lake level is a stratum of good clay which increases in hardnesss with the depth. The ground-water level rises on a slope of about 2 in. to 100 ft. going inland from the lake. The foundations and footings in many instances extend below the water level, but the heavy continuous bed of fine sand precludes any necessity of deep foundations, or of special provisions to carry the heavy loads imposed by many of the various structures.

The principal work required to prepare the site for the construction of the steel works was to level the sand dunes and the hollows to a uniform height of about 20 ft. above the lake level, although considerable areas are also being reclaimed from the lake, which is shallow along the site. While the leveling work was largely all done in advance of the construction, the sites of several large buildings and other structures were either excavated at the time, or were left until such time as they were to be utilized. The preparation of the site of the works, which is nearly a mile square, in this manner required great quantities of materials to be moved, but the excellent foundations afforded render this grading work an undertaking entirely of magnitude, rather than of difficulty.

The new works are to include sixteen blast furnaces, which are to be in a row parallel to a harbor about 6,000 ft. long and 250 ft. wide; These furnaces are being built partly on reclaimed land and partly on existing ground. A complete description of the plant and methods used in constructing the harbor was published in The Engineering Record of Aug. 17, 1907. Between the harbor and the row of furnaces are large traveling bridges for unloading ore from the vessels, rehandling bridges, ore storage piles, and pits for the charging skips of the furnaces. On the other side of the furnaces are the various buildings of the works, chief among which, from the standpoint of heavy foundations, are a blowing-engine house, a building for electrical generators and five large buildings for open-hearth furnaces. The foundations for most of these structures are massive concreae built directly on the sand. This concrete is all made in the proportions of 1 part cement, 3 parts limestone screenings and 6 parts crushed limestone. Universal and Newago Portland cement are used; the screenings vary from fine dust to pieces ¼ in. in extreme dimensions and the crushed stone will all pass a screen with 2-in. meshes but be retained on one with 1-in. meshes.

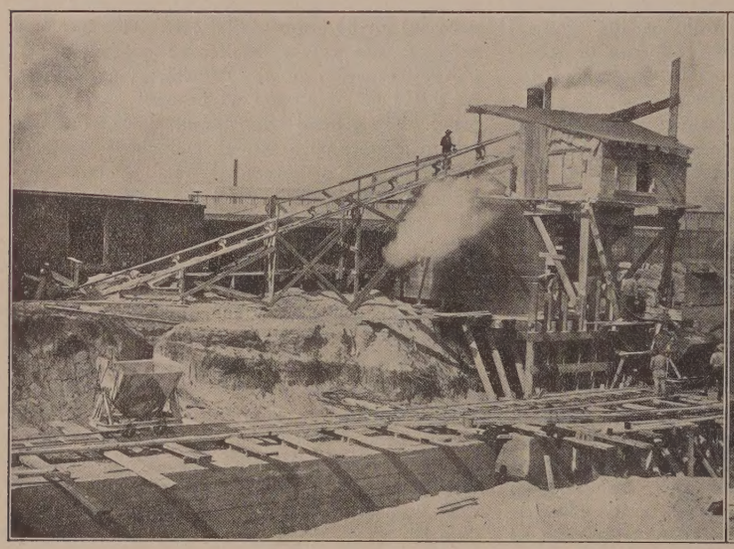
The construction of the greater part of the foundations that have been put under way is being carried on by Messrs. Lanquist & Illsley, general contractors, of Chicago. The plant and methods used in handling and mixing the great volumes of concrete in these foundations and footings have been specially developed to conform with the conditions presented. Railroad switching connections are in all cases extended directly to the work under way in order that plant and materials may be delivered expeditiously. In most cases the opportunity has also been afforded to handle the work in a logical manner. These conditions, and the great quantities of concrete to be placed in comparatively small areas render central mixing plants, with a large amount of equipment for handling the materials to, and the concrete away from these plants, the most productive and economical arrangement that could be made.

One general type of mixing plant has been adopted, and six of these plants have been erected adjacent to the heaviest work. Briefly, each of these plants embraces a belt conveyor, which delivers the concrete material from cars on a switch track to a mixer in an elevated tower; the mixer discharges into steel dump cars on portable narrow-gauge tracks extended to various parts of the work, or into bottom-dump buckets running on cars on these tracks to derricks which handle the buckets to place in the forms. The details and arrangement of these plants have been altered to suit conditions, but in all cases mechanical equipment has been used to eliminate manual labor as far as possible, and this equipment has been adopted in such form that it will handle the materials and concrete rapidly and in the most effective manner.

The foundations and footings for the blowing-engine house and the electrical generating station are among the most massive in the whole steel works, and the mixing plants that have been used during their construction are good examples of the general type. The blowing-engine house is approximately 135x600 ft. in plan, and will contain ten large blowing engines, operating on gases from the blast furnaces. The electrical generating station, of about the same size in plan, will contain fifteen gas-engine-generator units, each rated at 2,000 kw. These two buildings are adjacent, their longitudinal center lines being parallel.

The substructure of each building has as a base a monolithic concrete slab, about 135x600 ft. in plan and 5 ft. thick, or containing in round numbers, 15,000 cu. yd. of concrete. On this slab are built the foundations for the large blowing engine and generator units. These units are to be placed closely together in both buildings, so that but little space is available between the foundations of adjacent units; in most cases also the foundations extend from one side of the substructure to the other, a narrow space being left along on each side of the row of foundations, between the latter and the concrete walls, which are carried from the heavy base slab up to the superstructure walls. The foundations for the blowing engines are particularly heavy. The bottom of the 5-ft. base slab on which these foundations are built is at Chicago city datum, or about 1.5 ft. below the mean water level in the lake and 20 ft. below the finished ground surface. The foundations rise to 23 ft. above Chicago datum, or 18 ft. above the base, and are 40x80 ft. in plan in extreme dimensions. In the substructure of the electrical generating station the heavy base slab is at the same depth below the surface as in the blowing-engine house, and the foundations for the units in the station are about as heavy, each being, in general dimensions, also 40x80 ft. in plan and 18 ft. in height above the base slab.

The concrete for the substructure of each of these buildings was practically all mixed in a separate plant, although during the final work on the station substructure concrete for that work was furnished from the plant at the blowing-engine house. The arrangements and methods of operating both of these plants are so similar that a description of the plant for the substructure of the blowing-engine house will suffice for both.



Concrete Mixing Plant for Heavy Walls of Ore Bins.

Mixing Plant Delivering to Cars at Three Elevations.

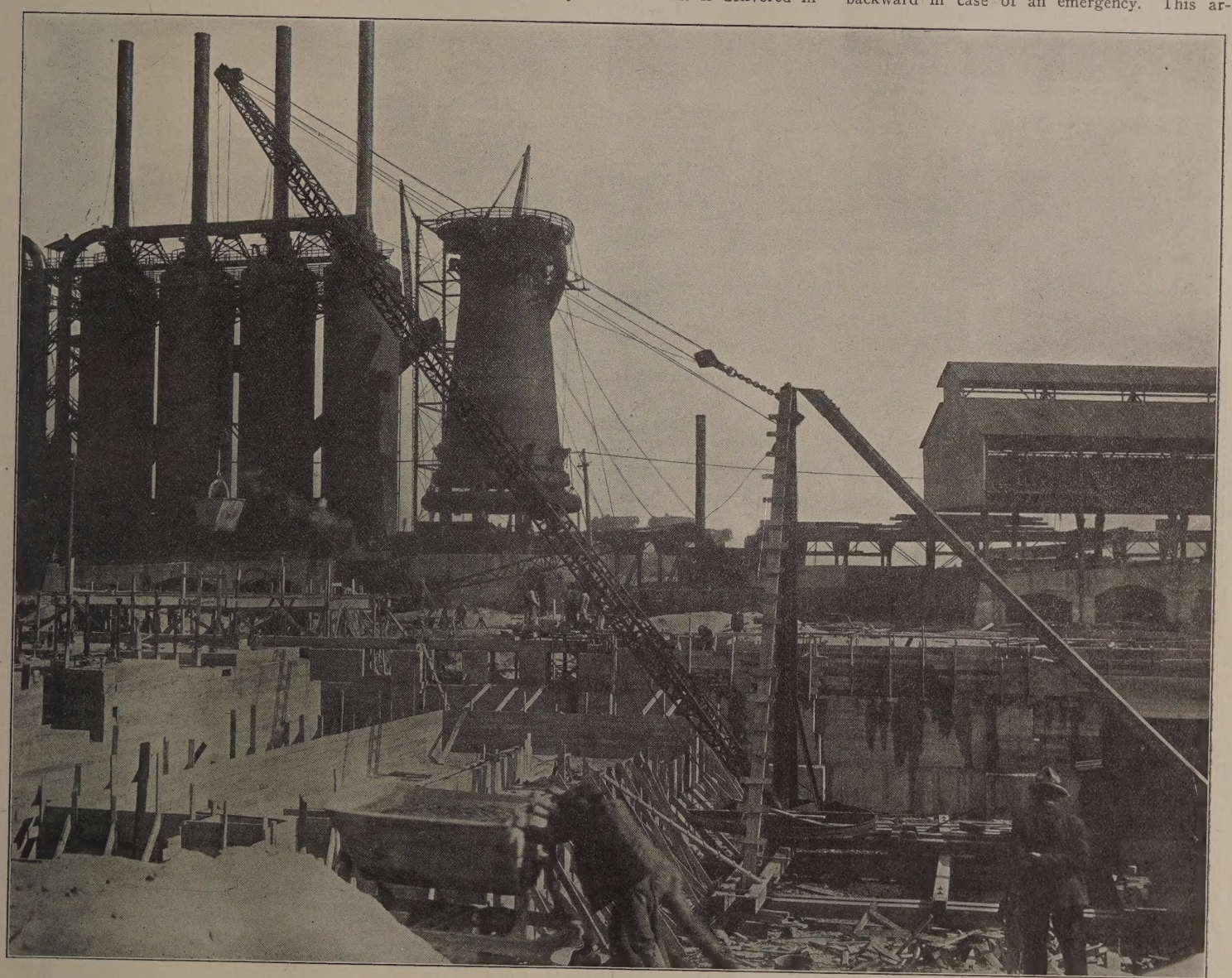
This plant was erected at the inland end of the building, where two switch tracks could be extended up to one corner of the building without interfering with operations on the latter, or with any of the other large construction work which is under way on all sides. A heavy timber tower was built at the middle of the end of the building, in the edge of the excavation for the substructure, a platform for the mixer being placed in this tower at about the existing ground level. A charging hopper, having sufficient capacity for some storage, was built in the tower over the mixer. The hopper was divided into two compartments, one for crushed stone and one for screenings, and is placed so its top is 20 ft. above the ground. A small charging hopper for the cement was also placed over the mixer, at a lower level.

The cement, screenings and crushed stone are delivered from cars on the two switch tracks to these elevated hoppers by belt conveyors. A horizontal belt conveyor is placed in a frame between the two tracks, which are 16 ft. apart on centers. This conveyor is low enough to permit materials to be discharged on it from Williamson side-dump cars on both tracks with a minimum amount of shoveling. The horizontal conveyor is 300 ft. in length so seven cars can be placed along it in a string on one track, one car for cement, two for screenings and four for crushed stone. Portable platforms are extended from the floor of the car to an opening in the top of the frame carrying the conveyor in order that the screenings and stone may be shoveled on the latter without loss.

The horizontal conveyor is a 28-in. belt traveling at a speed of 300 ft. per minute, and has a rated capacity of 60 cu. yd. an hour. It discharges the materials at the end on an inclined 24-in. belt conveyor, extending up to the charging hoppers, into which the materials are delivered by it. A swinging baffle board is arranged over the hoppers in such manner that when screenings or stone are being handled they can be diverted into their respective hoppers. A man on the mixer signals to the shovelers in the cars whether screenings or stone are wanted, both classes of material, of course, being supplied to the charging hoppers separately. The cement is delivered in sacks which are handled from the car to the conveyor at any time whether stone or screenings are being haindled. A man stationed near the top of the conveyor picks the sacks from the latter and places them on a short chute leading to a platform around the cement hopper. After the sacks are opened on this platform, the cement is poured into the charging hopper by hand.

The concrete mixer installed in this plant and also in the other plants on the work was designed specially for this work by the contractor. Essentially, it is of the continuous-mix pug-mill type, with an automatic feeding and measuring device. The latter has a short, solid cast-iron cylinder, with a series of four rows of pockets in its outer face; this cylinder is placed to a fairly close fit in a drum over one end of the drum of the mixer. The materials are fed into the mixer from the charging hoppers through this measuring device, the pockets in the cylinder of the latter being proportioned so the proper quantities of cement, screenings and crushed stone are supplied. The mixer and the measuring device are driven by the same engine, so the ratio between the rate of supply and the rate of mixing are constant, but may be varied.

The mixer is driven by a sprocket chain on a 40-h.-p., double-cylinder, steam engine. The conveyors are also driven by this engine, power being transmitted to them by a wire-cable rope drive. The engine is fitted with a reversing-motion link so the mixer and belts can be turned backward in case of an emergency. This arrangement has been found particularly satisfactory since it permits large stones, bolts and the like that occasionally become lodged in the mixer or belts to be removed without difficult



Derrick with 115-Foot Boom for Handling Concrete in Heavy Foundation Work at Gary, Ind.

Steam is supplied to the engine by a 60-h. locomotive-type, boiler set up at the side of plant the idea being in the choice of both e and boiler to have ample power for all d

The arrangement of tracks for handli crete in the dump cars and buckets mixer to place was altered from time suit conditions as the work progr 5-ft. base slab under the substructure all finished before work was star engine foundations. In order, hasten the beginning of work on section of the slab 20 ft. in widt forward on each side, from the

the opposite end of the substructure, after which the closing section at the middle was finished back toward the plant. This arrangement permitted an earlier installation, at the end farthest from the mixing plant, of a large derrick for handling the bottom-dump buckets used in placing the concrete in the upper part of the foundations.

The concrete in the base slab and in the engine foundations up to a height of 5 ft. about the slab was all delivered in the side-dump cars running on portable track, which extended from the mixing plant to the point where work was in progress. Above that height the concrete was placed from the bottom-dump buckets by the derrick. The portable track, of which the contractors have in the neighborhood of 10,000 linear feet on the whole work, was built in 15 ft. lengths by the Arthur Koppel Co. The cars are of the standard 1-yd. Koppel side-dump design having steel bodies, steel frames and ball-bearing wheels. Concrete is also dumped from these cars into the forms for the side walls of the substructure by placing an inclined deflector at the top of the form.

The bottom-dump buckets were designed by the contractors and have a capacity of 1½ cu. yd. each. Their bottoms are made in one piece which is hinged at one side and is locked in place at the other side by a hook clamp that is easily loosened when the contents are to be dumped. The sides of the bucket all converged toward the bottom in order to facilitate the removal of the concrete.

While concrete was being placed in the base slab the portable tracks were blocked up on the finished work, the cars being dumped on one side of the track, which was shifted as the work progressed. Within 150 to 200 ft. of the mixing plant the cars were pushed from the latter to place by hand. At a distance in excess of that the cars were drawn in pairs by a horse to the point where concrete was being laid. After work had been started on the engine foundations tracks were laid on temporary trestles extending over the forms for the foundations at a height of 12 ft. above the top of the slab. Later, as the walls around the substructure were being built tracks were laid from the mixer at a third level, 18 ft. above the slab and were continued along the tops of the forms of the walls. Finally, the lowest level of track was also used to deliver concrete to the derrick in the bottom-dumping buckets. The work was prosecuted in such sequence, however, that the concrete was being handled in all four ways simultaneously. The mixer discharged directly into cars at the lowest level at first; then a platform at the higher levels was started a bucket elevator, driven by the mixer engine, installed in the discharge chute leading from the mixer, in order to deliver the concrete to the higher levels without requiring the mixer to be placed on a high expensive tower, which would have necessitated longer inclined conveyors leading to the charging hopper. The chute into which the bucket elevator discharged was arranged with hinged deflectors so the concrete could be diverted into secondary chutes leading to the different levels.

When the mixing plant for the substructure of the electrical station was discontinued an incline was built from the second level of tracks at the mixer for the substructure of the blowing-engine house, up over the forms for the side walls of this substructure to a connection with the highest level tracks for the other substructure. The cars were drawn up this incline by a hoisting engine, and were fitted with a simple brake so two men could ride them down the incline with safety.

Except in the vicinity of the mixers the portable tracks at all three levels in both these substructures were laid singly, but were arranged with passing tracks which enabled several cars going in both directions to be in service on the single track. The arrangement of the tracks at the mixer permitted four cars to be set in position to receive concrete, thus avoiding any delay by waiting for cars. The latter could also be brought to and taken away from the mixer without interfering with the cars in position at the mixer. This method of arranging tracks to facilitate the delivery of cars to and from the mixer and to permit the operation of the largest economical number of cars on the running tracks, has been carefully and fully developed in a similar manner in connection with all of the mixing plants that have been built. At the same time, even with this complete system the output of the mixing plants is limited chiefly by a lack of ability to remove the concrete as fast as it can be produced.

The derrick used in handling the bottom-dump buckets in which the concrete is delivered to it for the upper parts of the engine foundations was also designed for this particular work by the contractors. It has a 40-ft. latticed steel mast with four wooden stiff legs and a bull-wheel. The boom is 115 ft. in length, which is believed to be one of the longest, if not the longest boom of this type that has been built. It is made up of four 6-in. steel angles, placed at the corners of a 24-in. square and latticed together. A platform on heavy timber sills carries the derrick and the double-drum 50-h.p. Monaghan hoisting engine used to operate it. The platform sills are on rollers running on the portion of the base slab of the substructure which has been finished, so the derrick can readily be moved.

The completion of the upper part of the engine foundations, for which the derrick delivers the concrete, was started at the end of the substructure farthest from the mixing plant, the derrick being placed far enough from that end so it could just reach the work in the latter. As the foundations were finished up to the derrick the latter was moved back until the work was completed about 50 ft. from the one end. Meanwhile, the lower part of the foundations in the rear of the derrick had been built nearly to mixer plant; the derrick is to be turned around so it can be used to finish this section of the foundations, after which it will be dismantled and the foundations in the closing section built from tracks by dumping from the cars.

The equipment, arrangement and operation of the other five mixing plants which have been built, and particularly of the plant for the substructure of the electrical station, are very similar to those of the plant that has been described. The equipment for all of them is practically the same, while the arrangement has been varied in details to suit the locality. The horizontal run of the belt conveyors is placed in the same manner as in the case of the one described, although in some of the plants only a single switch track is available. The position of the inclined run of the conveyors is governed by the proximity of the switch tracks to the mixing plant, as it has been found that a grade of 4 in. to the foot is the steepest at which crushed stone can be handled on the belt. The construction and arrangement of the mixer tower, however, is the same in all the plants; the general conditions governing the arrangement of the tracks on which the concrete is delivered from the mixer have been explained.

Horizontal Conveyor Belt for Delivering Concrete Materials from the Cars to a Mixing Plant.

The method of handling the work on the different heavy foundations is varied from the program followed in connection with the substructure of the blowing-engine house in order to suit local conditions. The work on the foundations for the substructure of one of the open-hearth furnace buildings will illustrate some of the changes that have to be made. These buildings are each 165x1,200 ft. in plan, their substructures having as a base a solid slab of concrete 2½ to 3½ ft. thick and 165x1,400 ft. in plan, the base being extended beyond both ends of the building. On this base are erected the massive concrete foundations for the open-hearth furnaces, for the columns of the building and for the heavy equipment in the latter. In executing this work a mixing plant was first set up at one end of the building and delivered concrete for most of the building substructure for a distance of 1,000 ft. from it. Then, in order to permit the erection of the superstructure to be started, the mixing plant was moved to the opposite end of the building, where it remained until the work was finished.

The sequence of operations on this building were much the same as on the one already described. Two traveling stiff-leg derricks with 35-ft. steels masts and 100-ft. steel booms were installed to handle the bottom-dump buckets used in placing the concrete in the upper part of the foundations, after the base slab and the lower part of the foundations had been placed from cars. These derricks were built prior to the construction of the one with the 115-ft. boom, the satisfactory results secured in their

operation having much to do with the installation of the one with the longer boom. At the same time it should be noted in this connection that these derricks handle about 2½ tons as maximum loads, their great advantage being in their long range at comparatively low heights.

The walls which carry the traveling ore unloaders and the rehandling bridges, and those along the ore storage bins parallel with the row of furnaces, all of which walls are parallel and close together, contain large quantities of concrete. The walls for the ore unloaders are 17 ft. wide at the base, 18 ft. high and 8 ft. wide on top; one leg of the rehandling bridges is carried by one of the walls for the unloaders, while the other leg is carried by a wall 17 ft. wide at the base, 10 ft. high and 8 ft. wide on top. The walls for the ore bins are not so high, but are more massive. A section of all these walls, 2,400 ft. in length, is being built by Messrs. Landquist & Illsley, who have erected two mixer plants for this work. In building the wide sections of the walls two parallel portable tracks are provided for the operation of the dump cars to and from the mixer plants. On the narrow sections of the walls single tracks with turnouts at frequent intervals are employed.

The quantities of concrete that are required to provide foundations for the principal structures of the new steel plant that are under construction are enormous. The contractors whose plant and methods have been considered herewith have already placed over 200,000 cu. yd. of concrete since they commenced operations in July, 1906, and their work will involve approximately 350,000 cu. yd. in the aggregate, besides requiring the handling of over 500,000 cu. yd. of sand. There is, furthermore, a large amount of concrete required in the other structures, buildings, dock walls and so forth in the steel works, not covered by their contract in addition to which may be included the concrete used for the municipal works of the town of Gary. These works were fully described in The Engineering Record of July 20, 1907.

Practically since the inception of operations the contractors have had in operation three to four mixing plants. The actual normal output of each of these plants is in the neighborhood of 350 cu. yd. per 10-hr. day, although occasionally a plant will deliver 450 cu. yd. in that time. In order to keep the plants in operation 30 to 50 cars of cement, screenings and stone have to be delivered each day. The materials are all furnished by the management of the steel plant, and due to an excellent system of switching which is followed, very little delay is experienced in delivering them. The stone and screenings are brought to the works in special trains directly from the extensive quarries of the Dolese & Shepard Co.

The design and construction of the new steel plant are under the direction of Mr. G. G. Thorp, vice-president of the Indiana Steel Co.; Mr. A. B. Neumann is chief engineer, and Mr. W. P. Gleason is superintendent of that company.

FUEL REQUIREMENTS in the vicinity of Boston are responsible for a decided novelty in the Atlantic coast-wise coal trade. The New England Coal & Coke Co. has under contract three 11-knot steam colliers which will replace sailing vessels in the coal trade from Virginia. The sailing colliers are often delayed for many days at a time in rounding Cape Cod, and as a result there are threatened shortages in fuel supplies and congestion at the unloading points when heavy weather continues for some time. The new steam colliers are designed to carry 7,200 tons each, and are to be fitted with appliances permitting them to be loaded and unloaded in 6 and 10 hr. respectively.

New Reinforced Concrete Regulations in Philadelphia.

The following regulations of the Bureau of Building Inspection of Philadelphia in regard to the use of reinforced concrete were approved by Director Henry Clay, of the Department of Public Safety, on October 8.

The term "reinforced concrete" shall be understood to mean an approved concrete mixture reinforced by steel or iron of any shape, so that the steel or iron will take up all the tensional stresses and assist in the resistance to compression and shear.

Before a permit to erect any reinforced concrete structure is issued, complete specifications and drawings shall be filed with the Bureau of Building Inspection, showing all details of the construction, size and position of all reinforcing rods, stirrups, etc., and giving the composition and proportions of the concrete.

The execution of the work shall be performed by workmen under the direct supervision of a competent foreman or superintendent.

Reinforced concrete construction will be accepted for fireproof buildings of the first class, if designed as hereinafter prescribed; provided, that the aggregate for such concrete shall be clean, broken, hard stone, or clean graded gravel, together with clean siliceous sand or fine grained gravel; should the concrete be used for flooring between rolled steel beams, clean furnace clinkers entirely free of combustible matter, or suitable seasoned furnace slag may be used; when stone is used with sand gravel it must be of a size to pass through a 1-in. ring, and 25 per cent. of the whole must not be more than one-half the maximum size; and provided further, that the minimum thickness of concrete surrounding the reinforcing members of reinforced concrete beams and girders shall be 2 in. on the bottom and 1½ in. on the sides of the said beams and girders. The minimum thickness of concrete under slab rods shall be 1 in. All reinforcement in columns to have a minimum protection of 2 in. of concrete.

All the requirements herein specified for the protection of steel and for fire-resisting purposes shall apply to reinforced concrete flooring betweeen rolled-steel beams as well as to reinforced concrete beams and to entire structures in reinforced concrete. Any concrete structure or the floor filling in same, reinforced or otherwise, which may be erected on a permanent centering of sheet metal, of metal lathing and curved bars or a metal centering of any other form, must be strong enough to carry its load without assistance from the centering, unless the concrete is so applied as to protect the centering as herein specified for metal reinforcement.

Exposed metal centering or exposed metal of any kind will not be considered a factor in the strength of any part of any concrete structure, and a plaster finish applied over the metal shall not be deemed sufficient protection unless applied of sufficient thickness and properly secured, as approved by the Chief of the Bureau of Building Inspection.

All concrete shall be mixed in a mechanical batch mixer to be approved by the Bureau of Building Inspection, except when limited quantities are required or when the condition of the work makes hand mixing preferable; hand mixing to be done only when approved by the Bureau of Building Inspection. In all mixing the material shall be measured for each batch.

When hand mixing is done under the aforesaid limitations, the cement and fine gravel or coarse sand shall be first thoroughly mixed dry and then made into a mortar by gradually adding the proper amount of water. The crushed stone or gravel shall be spread out to a depth not to exceed 6 in., in a tight box or upon a proper floor, and be sprinkled with water as directed; the mortar is then to be evenly spread over the crushed stone, and the whole mass turned over a sufficient number of times, to effect the thorough mixing of the ingredients.

All forms and centering for concrete shall be built plumb and in a substantial manner, made tight so that no part of the concrete mixture will leak out through cracks or holes, or joints, and after completion shall be thoroughly cleaned, removing shavings, chips, pieces of wood and other material, and no debris of any kind shall be permitted to remain in the forms. All forms to be properly supported and braced in a manner to safely sustain the dead load and the load that may be imposed upon them during construction.

The reinforcing steel shall be accurately located in the forms and secured against displacement.

Concrete shall be placed immediately after mixing.

Whenever fresh concrete joins concrete that is set, or partially set, the surface of the old concrete shall be roughened, cleaned and spread with cement mortar, which mortar shall be mixed in proportions of one of cement to two of sand.

Concrete shall not be mixed or deposited in freezing weather, unless precautions are taken to avoid the use of material covered with ice or snow or that are in any other way unfit for use, and that further precautions are taken to prevent the concrete from freezing after being put in place. All forms under concrete so placed to remain until all evidences of frost are absent from the concrete and the natural hardening of the concrete has proceeded to the point of safety.

Concrete laid during hot weather shall be drenched with water twice daily, Sunday included, during the first week. The broken stone, if hot and dry, must be wet before going to the mixer.

The time at which props or shores may safely be removed from under floors and roofs will vary with the condition of the weather, but in no case should they be removed in less than two weeks; provided, that column forms shall not be removed in less than four days; provided further, that the centering from the bottom of slabs and sides of beams and girders may be removed after the concrete has set one week, provided, that the floor has obtained sufficient hardness to sustain the dead weight of the said floor and that no load or weight shall be placed on any portion of the construction where the said centers have been removed.

The concrete for all girders, beams, slabs and columns, shall be mixed in the proportions of one of cement, two of sand or fine gravel, and four of other aggregates as before provided. The concrete used in reinforced concrete-steel construction must be what is usually known as a "wet" mixture. When the concrete is placed in water it must be placed in a semi-dry state.

Only Portland cement shall be permitted in reinforced concrete constructed buildings. All cement shall be tested, in carload lots when so delivered or in quantities equal to same, and report filed with the Bureau of Building Inspection before using it in the work. Cement failing to meet the requirements of the accelerated test will be rejected.

Soundness, Accelerated Test.—Pats of neat cement will be allowed to harden 24 hours in moist air, and then be submitted to the accelerated test as follows: A pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely-closed vessel, for 3 hours, after which, before the pat cools, it is placed in the boiling water for 5 additional hours.

To pass the accelerated test satisfactorily, the

pats shall remain firm and hard, and show no signs of cracking, distortion or disintegration.

Such cements, when tested shall have a minimum tensile strength as follows: Neat cement shall, after one day in moist air, develop a tensile strength of at least 150 lb. per square inch; and after one day in air and six days in water shall develop a tensile strength of at least 500 lb. per square inch; and after one day in air and 27 days in water shall develop a tensile strength of at least 600 lb. per square inch. Cement and sand tests composed of one part of cement and three parts of crushed quartz shall, after one day in air and six days in water, develop a tensile strength of at least 175 lb. per square inch, and after one day in air and 27 days in water shall develop a tensile strength of at least 240 lb. per squre inch. These and other tests as to fineness, set, etc., made in accordance with the standard method prescribed by the American Society of Civil Engineers, may, from time to time, be required by the Bureau of Building Inspection.

Walls.—Reinforced concrete may be used in place of brick and stone walls, in which cases the thickness may be two-thirds of that required for brick walls as shown in the Schedule, Section 18 of the Act of Assembly No. 123, of the Commonwealth of Pennsylvania, approved June 5, 1901, provided the unit stresses as set forth in these regulations are not exceeded.

Concrete walls in such cases must be reinforced in both directions in a manner to meet the approval of the Chief of the Bureau of Building Inspection.

Steel.—All reinforcements used in reinforced concrete shall be of standard grade of structural steel or iron of either grade to meet the "Manufacturers' Standard Specifications," revised February 3, 1903.

Reinforced concrete slabs, beams and girders shall be designed in accordance with the following assumptions and requirements:

(*a*) The common theory of flexure to be applied to all beams and members resisting bending.

(*b*) The adhesion between the concrete and the steel is sufficient to make the two materials act together.

(*c*) The design shall be based on the assumption of a load four times as great as the total load (ordinary dead load plus ordinary live load).

(*d*) The steel to take all the tensile stresses.

(*e*) The stress-strain curve of concrete in compression is a straight line.

(*f*) The ratio of the moduli of elasticity of concrete to steel:

Stone or gravel concrete	1 to 12.
Slag concrete	1 to 15.
Cinder concrete	1 to 30.

The allowable unit transverse stress upon concrete in compression:

Stone or gravel concrete	600 lb. per sq. in.
Slag concrete	400 " " " "
Cinder concrete	250 " " " "

The allowable unit transverse stress in tension:

Iron	12,000 lb. per sq. in.
Steel	16,000 " " " "

The allowable unit shearing strength upon concrete:

Stone or gravel concrete	75 lb. per sq. in.
Slag concrete	50 " " " "
Cinder concrete	25 " " " "

The allowable unit adhesive strength of concrete:

Stone or gravel concrete	50 lb. per sq. in.
Slag concrete	40 " " " "
Cinder concrete	15 " " " "

The allowable unit stresses upon concrete in direct compression in columns:

Stone or gravel concrete	500 lb. per sq. in.
Slag concrete	300 " " " "
Cinder concrete	150 " " " "

The allowable unit stress upon hoop columns composed of stone or gravel concrete shall not be over 1,000 lb. per square inch, figuring the net area of the circle within the hooping. The percentage of longitudinal rods and the spacing of the hoops to be such as to permit the concrete to safely devolp the above unit stress with a factor of safety of four.

When steel or iron is in the compression sides of beams the proportion of stress taken by the steel or iron shall be in the ratio of the modulus of elasticity of the steel or iron to the modulus of elasticity of the concrete provided that the rods are well tied with stirrups connecting with the lower rods of the beams; provided, further, that when rods are used in compression, the approval of the Chief of the Bureau of Building Inspection must be obtained.

In the design of structures involving reinforced concrete beams and girders, as well as slabs, the beams and girders shall be treated as T-beams, with a portion of the slab acting as flange in each case. The portion of the slab that may be used to take compression shall be dependent upon the horizontal shearing stress that may exist in the beam, and in no case shall the slab portion exceed twenty times the thickness of the slab.

All reinforced concrete T-beams must be reinforced against the shearing stress along the plane of junction of the rib and the flange, using stirups throughout the length of the beam. Where reinforced concrete girders carry reinforced concrete beams, the portion of the floor slab acting as flange to the girder must be reinforced with bars near the top, at right angles to the girder, to enable it to transmit local loads directly to the girder and not through the beams, thus avoiding an integration of compressive stresses due to simultaneous action as floor slab and girder flange.

In the execution of work in the field, work must be so carried on that the ribs of all girders and beams shall be monolithic with the floor slabs.

In all reinforced concrete structures special care must be taken with the design of joints to provide against local stresses and secondary stresses due to the continuity of the structures.

Shrinkage and thermal stresses shall be provided for by the introduction of steel.

In the determination of bending moments due to the external forces, beams and girders shall be considered as simply supported at the ends, no allowance being made for continuous construction over supports. Floor slabs, when constructed continuously, and when provided with reinforcement at top of slab over the supports, may be treated as continuous beams, the bending moment for uniformly distributed loads being taken at not less than $WL/10$ in cases of square floor slabs which are reinforced in both directions and supported on all sides, the bending moment may be taken at $WL/20$; provided, that in floor slabs in juxtaposition to the walls of the building the bending moment shall be considered as $WL/8$, when reinforced in one direction, and if the floor slab is square and reinforced in both directions, the bending moment shall be taken as $WL/16$.

When the shearing stresses developed in any part of a reinforced concrete building exceed under the multiplied loads the shearing strength as fixed in this section, a sufficient amount of steel shall be introduced in such a position that the deficiency in the resistance to shear is overcome.

When the safe limit of adhesion between the concrete and steel is exceeded, provision must be made for transmitting the strength of the steel to the concrete.

Reinforced concrete may be used for columns in which the ratio of the length to least side or diameter does not exceed 15. If more than 15 diameters the allowable stress shall be decreased proportionally. Reinforcing rods that are introduced for lateral stresses must be tied together at intervals of not more than the least side or diameter of the columns.

Longitudinal reinforcing rods will not be considered as taking any direct compression.

The contractor must be prepared to make load tests in any portion of a reinforced concrete building within a reasonable time after erection, and as soon as may be required by the Chief of the Bureau of Building Inspection. The tests must show that the construction will sustain a load equal to twice the calculated live load without signs of cracks.

Systems of construction differing from the standard already approved and tested, may be required to pass a load, fire and water test, as present in Section 2 of the Act of Assembly, No. 236, of the Commonwealth of Pennsylvania, approved April 25, 1903.

The Chief of the Bureau of Building Inspection may, from time to time, issue such modifications to these regulations as may be found necessary to conform to modern practice.

General Appearance of Retail Coal Pockets at Hoboken.

Glass Telegraph Poles are to be manufactured in a factory recently built at Grossahmerode, Germany. An architect, of Cassel, has been granted patents in Germany and other European countries and in the United States for a machine to be used in their manufacture, according to United States Consular Agent Gustav C. Kothe, of Cassel. The glass is reinforced by wires suitably disposed. These poles, it is believed, will be particularly adapted for use in countries where wooden poles are quickly destroyed by insects or climatic conditions. The Imperial Post Department of Germany has ordered these poles for use on one of its telephone or telegraph lines. A pole 23 ft. long costs about $6 now but the regular selling price for market quotation has not yet been announced.

A Modern Retail Coal Pocket.

By Charles J. Steffens, Manager Guarantee Construction Co., New York.

The past few years have shown a marked advance in many branches of engineering, but none more marked than in that of the mechanical handling of materials. With the steadily increasing cost of labor, especially in the larger cities, it is becoming more essential as time passes that the labor cost at plants of every description be reduced to a minimum, and this requirement has resulted in the development and improvement of labor-saving appliances. While many technical articles have recently appeared on the subject, especially in connection with the handling of coal and disposal of ashes at the large power stations now being erected or recently completed, little has been written of the mechanical handling of coal at the retail yards. When one considers the enormous tonnage required to supply the inhabitants of any large city, the importance of this problem may readily be appreciated.

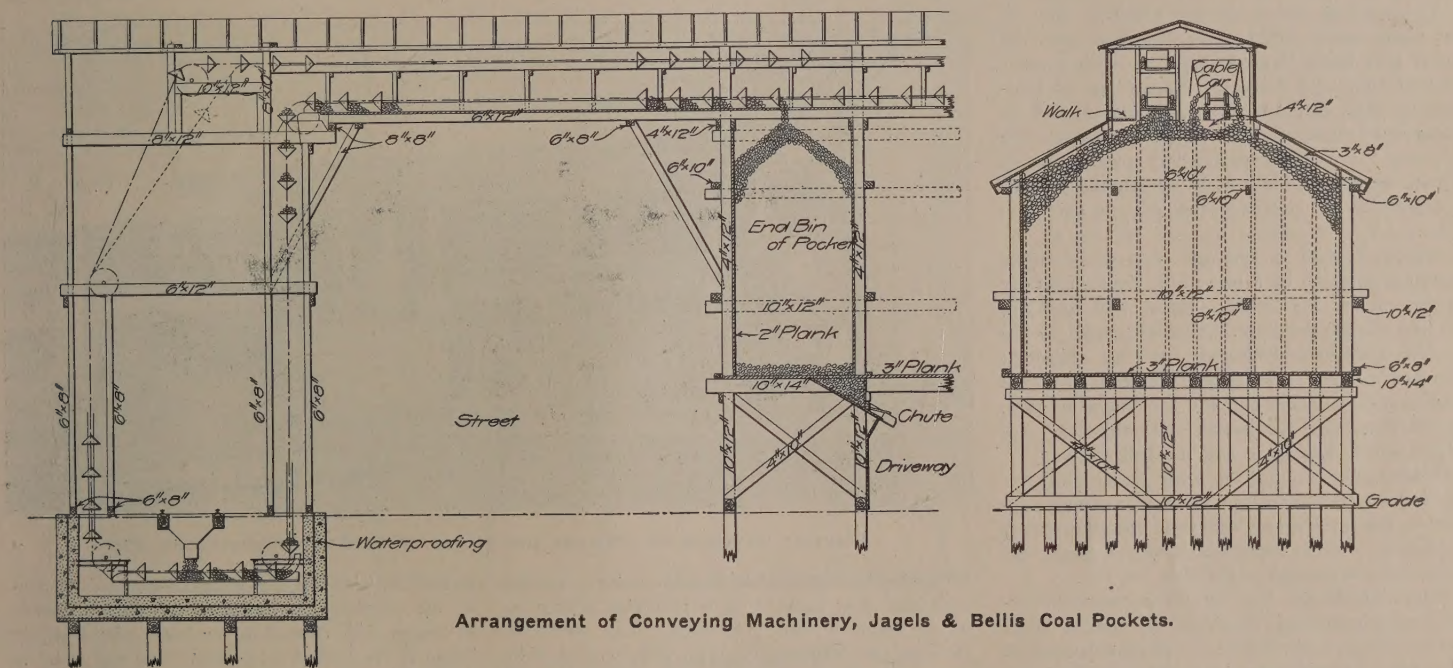
Simple as it may appear to design a plant of this character, yet in reality, if the plant, when completed, is to result in a minimum cost for operating expense and a minimum amount of breakage to the coal handled, it involves close study of the local conditions and a thorough knowledge of the various appliances for handling coal which are now on the market.

To the retail dealer there are but three ways of increasing his profits and thus meeting competition. The cost of coal at the mines is a fixed charge, as also is the freight, and these he cannot alter. His profits therefore can only be increased by a reduction of expenses after the coal is delivered at his plant, and this may be accomplished by reducing the percentage of coal broken in handling, by improved facilities which will enable him to handle his output at less expense, and by reducing the amount of waste product of his plant, consisting of screenings.

While it is true that the local conditions vary, and that no rule may be made which would apply to all cases—while in some instances an elevated trestle is undoubtedly the most economical form of plant—yet in general it may be said that the elevated pocket best suits the requirements of modern conditions. In a plant of this character, if properly designed, coal may be taken from the cars, loaded into the pocket and screened and delivered to the trucks at a cost which should not exceed two cents per ton, and is often more nearly 1½ cents. A plant of this character will cost when completed approximately $6.50 per ton of storage. This would, of course, include all foundations and machinery.

One of the largest retail coal firms in the east is the Jagels, Bellis Co., of Hoboken, N. J., who handle about 250,000 to 300,000 tons of coal per year and have several plants located in Hoboken, Jersey City and Weehawken. One of these plants is at 15th and Bloomfield Streets, Hoboken, N. J., of which a picture is given. Coal may be received by either rail or water, and the plant being within three blocks of the ferry to New York, the location leaves little to be desired.

At one side of the picture may be seen the hoisting tower, which forms the northerly end of the plant and is connected to the pocket by a timber trestle. At the south end of the pocket is a wooden bridge, spanning the street and extending to the elevator towers, where coal is taken from the cars. Beyond the elevator is a steel bridge over the tracks of the Hoboken Shore Road and connecting with the power-house of the Public Service Corporation, which the Jagels, Bellis Co. supplies. A screen pocket is located near the hoisting tower and here the screenings from the chutes of the pocket are resized for commercial use. The office, which is two stories high, is located opposite the south end of the pocket.



Arrangement of Conveying Machinery, Jagels & Bellis Coal Pockets.

The pocket is built of long leaf yellow pine, the foundations being spruce piles driven to such a depth as to secure a penetration of not more than 2½ in. under the last five blows of a 2,000-lb. hammer having an effective fall of 10 ft. Rows of posts under the pocket and supporting the floorbeams are spaced 12 ft. apart, thus providing alternately for a 12-ft. driveway and a 12-ft. space for storage of dust from the delivery chutes. These chutes are so arranged that about 90 per cent. of the coal may be drawn from the bins and delivered to the trucks without shoveling.

The pocket is 145 ft. in length and 31 ft. in width, with a depth for 21 ft. of coal in the bins, thus giving a capacity of approximately 3,000 tons if the coal is trimmed by hand or 2,700 tons without trimming. The floor is elevated 12 ft. from the ground so that the trucks may be driven underneath and there loaded. Eleven bins are provided for storage of the commercial sizes of anthracite, no bituminous coal being handled through the pocket.

At the southern end of the pocket is a public roadway, beyond which is the siding for delivering coal cars, and at this siding are located the elevator towers and also a small engine and winch used for moving cars along the tracks. The illustration shows a view of the tower and operation of the elevator.

The elevator is arranged to take coal from a steel trough under the track hopper and carry it horizontally to the end of the track pit, then vertically to a level with the top of the bins, and from this point horizontally over the street and to the north end of the pocket, with provision for discharging into any of the various bins as it passes along. Buckets are V-shaped, 24-in. long, 20 in. wide and 10 in. deep, and are spaced every 36 in., being bolted between two strands of chain composed of steel links of 18-in. pitch with a pin connection for the links. Four-inch rollers are provided on the pins, the rollers being so constructed that they may be automatically oiled by a suspended oiler while the machine is in motion.

The trough along which the coal passes on the horizontal run is made of No. 10 gauge steel and is provided with a discharge gate at the center of each bin, the gates being operated by a rack and pinion connected to an 18-in. handwheel. In order to avoid the breakage due to coal falling from the trough to the bottom of the bins, break preventors are provided under each discharge gate. These are so constructed that the coal is retarded in its fall, striking baffle plates so arranged that the greatest vertical drop for the coal is 2 ft.

At the north end of the pocket is a machinery room in which is located a 25-h.-p. direct-current 500-volt motor which runs at the speed of 1,100 r. p. m. The motor is geared down to the head-shaft of the elevator, the head-shaft being fitted with an equalizing gear to prevent the uneven motion of the buckets, which would otherwise result from having an 18-in. pitch chain. The elevator speed is 90 ft. per minute and the capacity is 60 tons per hour.

As the height of the tide rendered it necessary to make the track pit at the foot of the elevator waterproof, it was constructed in the following manner: Piles to support the weight of the pit were first driven, after which sheet piling of 2-in. plank was driven to a depth of 12 ft. and the earth excavated. A sump hole was also excavated adjacent to the pit, and a pump installed to keep down the water during construction. The piles were then cut off and capped with 12 x 12-in. yellow pine over which a 3-in. plank floor was laid, after which the outer walls

and floor were constructed of concrete 12 in. thick. When this had hardened, the inner forms were removed and all holes pointed up, after which waterproofing was applied, consisting of six layers of single-ply tar roofing felt, each layer as placed being coated with coal tar pitch, applied hot. The inner concrete walls and floor were then constructed, these being of the same thickness as the outer walls. This pit has been found thoroughly satisfactory and absolutely watertight.

Delivery chutes and gates, for loading the trucks, are made of sheet steel, each chute being provided with a screen 2 ft. wide and 3 ft. long over which the coal passes as it is discharged to the trucks. The size of mesh used in these screens for the various sizes of coal is as follows:

Pea, 3/16 in.; chestnut, ¼ in.; stove, ⅜ in., and egg, ½ in. The chutes will discharge at the rate of one ton per minute, if the gates are fully opened. Dust and small coal which passes through the screens are taken away at intervals and resized at the screen pocket which is located at the bulkhead.

The hoisting tower, at the northerly end of the plant, is also constructed of yellow pine, the lower part being formed into a bin with a capacity of about 300 tons, for the storage of bituminous coal. Bituminous coal is also stored on the ground under the trestle which connects the hoisting tower and pocket. The tower is 22 ft. square and 75 ft. high, with foundations of concrete, which rest partly on the crib and partly on piles.

Equipped with a one-ton clam-shell bucket which is operated by a 10 x 12-in. double-cylinder steam engine, the tower is capable of handling 60 tons of coal per hour. All coal hoisted by the bucket is discharged into the receiving hopper at the head of the hoist and on a level with the engineer's platform, so that the engineer may, at all times, see the bucket. On this level are also located the engine and the boiler.

When anthracite coal is being hoisted, the receiving hopper discharges into an auxiliary hopper on the level below and from this the coal is loaded into cable cars which run through the pocket and discharge to the bins.

Bituminous coal may be taken from the receiving hopper and by-passed through a chute to the storage bin below, or it may be passed through a crusher between the receiving and auxiliary hoppers, then into the auxiliary hopper and be conveyed to the Public Service Corporation's power-house by means of the cable cars.

In order to secure a uniform and satisfactory feed to the crusher, an apron feeder is located under the receiving hopper. The feeder is 24 in. wide and about 4 ft. long, running at a speed of 30 ft. per minute. The head shaft is geared to a countershaft, and this in turn driven from the line shaft. A tight and loose pulley on the belt drive provides for stopping the feeder when it is desired to handle coal without passing through the crusher.

The crusher is of the two-roll type with removable teeth fitted to 18 x 24-in. rolls, and is operated at a speed of 180 r. p. m., being driven from the line shaft by means of a 10-in. double leather belt. The belt pulley on the line shaft is fitted with a clutch so that the crusher may be cut out when desired.

Starting from a point under the auxiliary hopper and passing over the bins of the pocket, then over the bridge and to the power-house of the Public Service Corporation, is a car system of the shuttle type consisting of one-ton, steel, side-dump cars on a narrow-gauge track.

Three pulleys on the line shaft, the outer ones tight and the center one loose, are connected by two belts to a jack shaft on which are three similar pulleys. One of these belts is crossed and the other open, so that by means of a belt shifter the jack shaft may be caused to revolve in either direction, thus reversing the motion of the cable and cars.

Cars are automatically dumped over the bins so that when the tower is in operation, it requires an engineer to hoist coal and his assistant to load the cars and operate the belt shifter. Power for the feeder, crusher and car system is furnished by a 30 h.-p. 500-volt direct-current motor at a speed of 975 r. p. m. The motor is geared to the line shaft in the tower and is on same level as tracks of the car system.

At the north end of the plant, near the hoisting tower and on the bulkhead line, is a screen pocket 12 ft. wide, 30 ft. long and having a depth of 15 ft. in the bins, which are elevated from the driveways similar to the arrangement for the storage pocket.

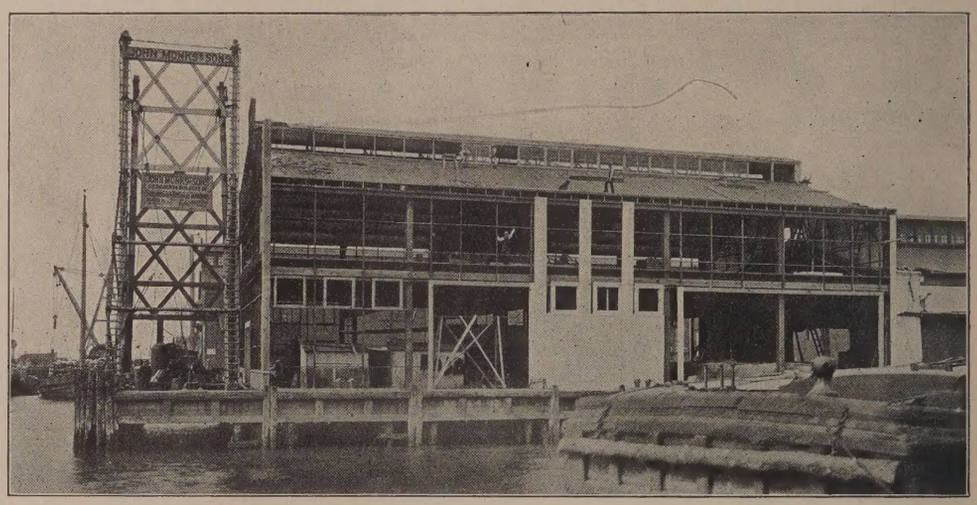
Small coal and dust which has passed through the screens of the chutes under the pocket is carted to the screen-house and there discharged into a small pit. From this point it is handled and sized automatically, being hoisted by a centrifugal discharge bucket elevator, with 5 x 7-in. malleable iron buckets, to a revolving screen 42 in. in diameter and 8 ft. long. The screen is mounted on trunnion bearings and covered with wire cloth, the mesh of the various sections being such as to size for dust, buckwheat and pea; chestnut and any other larger sizes pasing out over the end of the screen. Each size, as it is separated by the screen, is discharged into its proper bin from which it may be loaded to the trucks for delivery. Both screen and elevator are driven by a 7½ h.-p. motor.

The Effect of Compressed Air on health has lately been under investigation by two English engineers, who submitted themselves to some heavy pressures during the tests. A steel chamber was built, according to "The Engineer," in which the pressure was frequently raised to 75 lb. per square inch, without serious effect on the experimenters. Other tests showed that it is possible for a man to endure a pressure of 92 lb. per square inch without unpleasant results, provided that, first, at least twenty minutes are allowed for taking off each 15 lb. of pressure, the decompression being at a uniform rate; and, secondly, that the capillary circulation in every part of the body is maintained by muscular action during decompression. The only inconvenience under the pressure noted was a little temporary neuralgic pain in the arms. The studies further led to the belief that the longer the exposure, the longer and more uniform should be the decompression.

Reconstructing a New York Pier Shed.

The river end of the shed occupied by the Clyde Steamship Line on Pier 36, North River, New York, has recently been replaced by a modern steel structure of about the same width and about 10½ ft. higher. The new structure, about 114 ft. long and 73 ft. wide, is seated on the old wooden pier and has six transverse bents designed in accordance with recent practice for the construction of steel pier sheds. Each bent is about 32 ft. high to the eaves, and 54 ft. high over all, including the monitor, 5 ft. high. It is two stories high with the second floor 20 ft. above the deck of the pier and nearly 10 ft. in the clear below the lower chords of the roof trusses. The second floor is carried by a plate girder 6 ft. deep in each bent and both girders and roof trusses are supported entirely by the wall columns, leaving the interior of the shed unobstructed by intermediate columns.

Each bent is made with two 12 x 12-in. I-shape wall columns and a riveted triangular roof truss with a span of 73 ft. out to out and a center depth of 13 ft. 9⅜ in. The trusses are field



Traveler Revolved 90 Degrees and Stored on End of Reconstructed Pier.

riveted through vertical flange angles to the tops of the columns and are knee-braced with pairs of angles shop riveted to the lower chord gusset plates at the first panel points. The end panel is reinforced by a pair of angles back to back, inclined to the horizontal, which connects the gusset plates at panel points and materially stiffens the truss there. The 12-in. web plate of the 6 x 12-in. T-shape top chord is wide enough to provide connections with all the web members of the truss except at the center and ends where it is spliced to wide gusset plates. Pairs of angles are used for the bottom chord and single 2½ x 2½-in. angles are used for all of the web members, except at the center and quarter points of the span where pairs of 3 x 3½-in. angles are used to make a star shape cross-section.

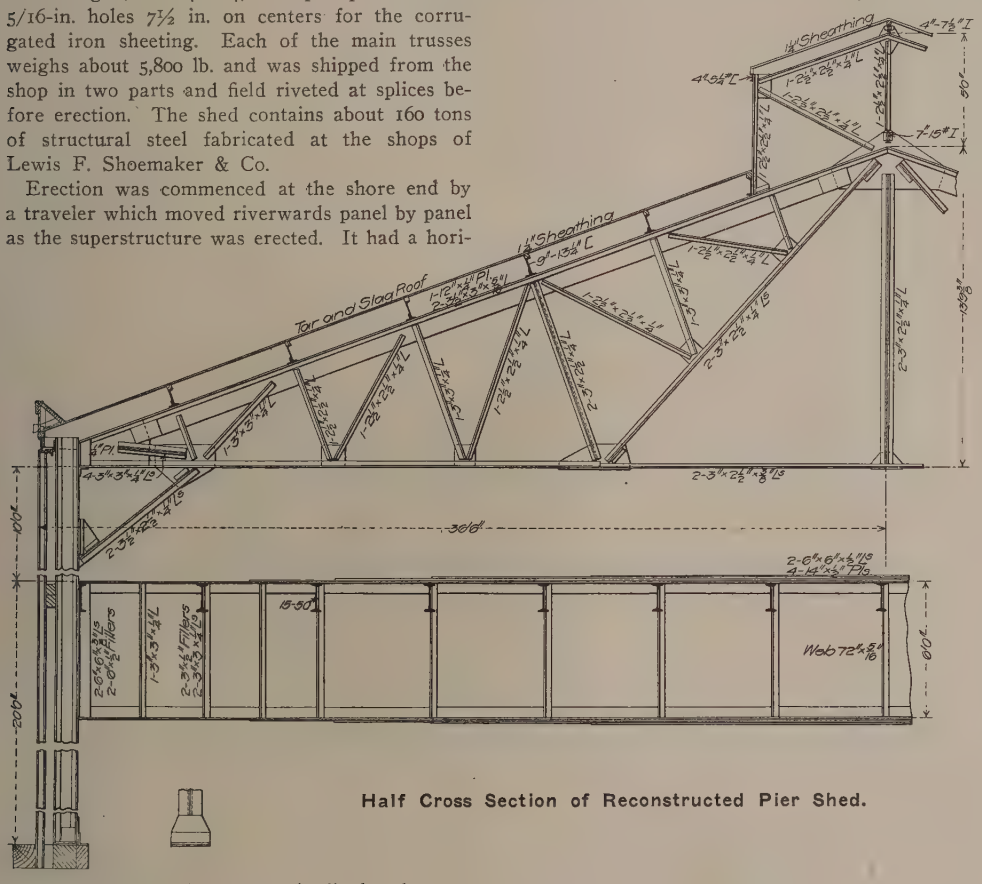
There are 12 lines of 9 x 13¾ lb. purlin channels on the main roof and three lines of 4-in. beam and channel purlins on the monitor frame 11 ft. 4½ in. apart which are supported on the main trusses and intermediately by the purlins. The purlins are secured to the rafters by short angle iron clips and have 2 x 2-in. nailing strips on their top flanges to receive the 1¼-in. sheathing boards covered with 5-ply of tar and slag roofing. The roof boards are finished at the eaves with a vertical fascia board and an inclined gutter board over which the water-proofing is flashed up to make an eaves trough. Vertical 4-in. I-beams are furred out 4 in. beyond the outer faces of the columns to provide frames for the large doors about 18 ft. square which occupy 3 of the panels in each side of the building. The

other two alternate panels have windows in the upper part and are sway-braced with ⅞-in. diagonal rods corresponding to the two sets of lateral rods in the same panels of the roof trusses.

The floor beams have web plates 5/16-in. thick and duplicate top and bottom flanges each made with a pair of full length 6 x 6 x ½-in. angles and four 14 x ½-in. cover plates from 26 ft. to 56 ft. long. The web is divided into 5-ft. panels by pairs of 3 x 3-in. vertical angles to the upper ends of which are field riveted the webs of 15-in. 50-lb. I-beam stringers with the top flanges bearing against the top flanges of the floor beams. Nailing strips on top of the stringers support the double plank floor clear of the rivet heads in the floor beam flange.

The end and side walls have 4-in. I-beam studs from 5½ to 7½ ft. apart and 2 x 2 ¼-in. horizontal angles from 4 to 4½ ft. apart punched with 5/16-in. holes 7½ in. on centers for the corrugated iron sheeting. Each of the main trusses weighs about 5,800 lb. and was shipped from the shop in two parts and field riveted at splices before erection. The shed contains about 160 tons of structural steel fabricated at the shops of Lewis F. Shoemaker & Co.

Erection was commenced at the shore end by a traveler which moved riverwards panel by panel as the superstructure was erected. It had a horizontal platform made with longitudinal and transverse sills braced to a pair of vertical masts about 65 ft. high and 20 ft. apart which were braced together with horizontal struts and triple intersection diagonals. Each mast had a 60-ft. 10-ton boom with which the columns of each bent were simultaneously erected. The columns remained supported by the booms until the floor girder was hoisted by tackles suspended from the masts direct, and set in position and connected to them, after which the booms were released and erected, the longitudinal stringers bracing the incompleted bent to the last finished bent. Finally the booms erected the roof truss and held it in position until connected to the columns and braced by the purlins which were hoisted by hand. A total force of 26 men including two gangs of riveters were required to operate the traveler and assemble and connect the steelwork. After erecting the last bent the traveler was revolved 90 deg. around a vertical axis and was left standing on the outer end of the pier as shown in the engraving until it was convenient to move it bodily on a lighter for the erection of another pier shed. The pier was designed and erected by John Monks & Sons, Mr. John W. Ripley, chief engineer of the structural department.



Half Cross Section of Reconstructed Pier Shed.

The Mechanical Plant for the Construction of the Tauern Tunnel in Austria.

In 1901 the Austrian State Railroads began the construction of three new lines which were planned to strengthen the commercial position of Austria and secure for the city of Triest, on the Adriatic Sea, a larger share of that part of the export trade of Austria, Germany and Italy, which now goes mainly by way of Hamburg, Genoa and Venice. The new lines connect the heart of Austria by short hauls with Triest and with the connection to the German railroads, and while facilitating passenger traffic from Germany and all parts of Austria to the famous health and scenic resorts, will also have a deep influence upon the freight traffic, since they shorten the distance from Triest to Salzburg by 43 per cent., the distance from Triest to Munich, 28 per cent., from Triest to Leipzig, 20 per cent., and from Triest to Berlin 17 per cent.

The standards on all three lines are very high and require much heavy cutting, long bridges and viaducts and quite a number of tunnels. Much of their total distance lies in mountainous country. One of the lines, that from Klagenfurt to Triest has no less than 32 tunnels, one of which, the Karawanken Tunnel, is 26,166 ft. or about 5 miles long, and another, the Wocheiner Tunnel, is 20,796 ft. or about 4 miles long. The second line running north from Selztal has a tunnel 15,648 ft. long and the last of the new roads, the Tauern Bahn, has the longest tunnel, 27,970 ft. or about 5 1/3 miles. The mechanical plant described was used at the last mentioned tunnel.

The first two of the new lines, and practically all of the work on the last line, with the exception of the Tauern Tunnel, were completed by the first of this year. The Tauern Tunnel, however, was not finally cut through until last July and at the present time the finishing touches are being put upon it. The remainder of the Tauern line has been in operation since September, 1905, and the entire line will be in use on the completion of the tunnel. The latter lies in the Tauern Mountains in Tyrol, a few miles south of the famous watering place, Bad Gastein.

The tunnel was driven simultaneously from both portals, at Boeckstein on the north, and Mallnitz on the south. The work was started first in 1901 at the north portal, the beginning at the south portal being purposely left over to the following year. The original mechanical installation at the north portal consisted of two ventilating fans driven by a 120-h.-p. water turbine and two Brandt twin reciprocating high pressure pumps, for furnishing water to the hydraulically-operated rock drills, driven by a 200-h.-p. water turbine. The machine shop, a blacksmith shop for caring for both hand and machine drills and an electric lighting plant completed the installation. All of the machinery was driven by water power, the total developed approximating 350 h.-p.

The ventilating fans have a diameter of 59 in. and a capacity of about 40,000 cu. ft. of air per minute. The turbine driving the high pressure pumps for supplying water to the drills makes 200 r. p. m., and transmits its power to the reciprocating pumps through gearing engaging on a crank shaft. The water is put under a pressure of 1,500 lb. per square inch and is led into the tunnel through a 3-in. pipe which is reduced to a 2-in. pipe near the face of the work. From the latter it is delivered to the drills through a flexible pressure hose.

The Brandt drills make from 5 to 10 r. p. m., and have a total pressure on the drill rod of 26,000 lb. In the exceptionally hard rock encountered in the work the daily progress was about 17 ft. in 24 hr., and the maximum progress about 24 ft. in the same time.

The final installation of the plant just referred to was not completed until September, 1903, and the work had scarcely been taken up in full force when a bad flood in the valley ruined part of the dam of the water power system, carried away some of the supports of the high pressure water pipe so that in places distances as great as 262 ft. remained suspended between supports, and flooded the power plant. The stream, which originally had crossed over the tunnel but which had been confined in an artificial channel, returned to its bed and broke through the roof of the tunnel with a flow of approximately 140 cu. ft. per second. The damage, however, was quickly repaired and the work again taken up with full force.

The entire original installation of machinery was of a temporary character, it being intended to add to it as the demands became greater. The building, however, in which the equipment was housed had been designed to take care of the entire final plant. It was the intention to make the increase in the equipment toward the end of 1904 and at the same time to let out the work by contract, but various circumstances caused the delay of both until December, 1905. A contract was then let to Redlich Bros. & Berger for the entire excavation of the remainder of the tunnel at both portals. As a result of this delay in increasing the size of the plant, the original installation, which had been designed to last but two years, had to be used for over three years, and an investigation was accordingly made to learn what steps should be taken to make it last until the tunnel was finally completed. In this investigation advantage was taken of the studies upon the ventilating equipment which had been made at the Wocheiner Tunnel. The figures showed that the original plant could pull through until the load [illegible] was lessened by the new installation an[illegible] continue to give service till the tunnel w[illegible] pleted by substituting larger pipes in t[illegible] alting system and reducing somewha[illegible] of drilling and the lighting during

of 1905. The theoretical result of this investigation was fully borne out by experience, for though the original plant was heavily overworked, it kept the excavation moving until the new plant was installed.

Previous to the installation of the new equipment a zone of soft rock was encountered, which not only delayed the work considerably, but made it dangerous. Through this section the only timbering found necessary in the tunnel was used.

In increasing the size of the plant it was determined in as far as possible to use the machinery from the three large tunnels which had already been completed on the other new lines. At the same time the equipment was so planned and arranged as to give the most economical results and reduce operating expenses. Similar plans were made at the same time for the installation at the south portal of the tunnel, the machinery here, too, being all second-hand, such repairs and changes being made as were necessary to secure satisfactory and economical operation.

It was estimated that about 19,500 ft. of the tunnel would be driven from the north side and the figures derived from the earlier experience at the same tunnel showed that three more groups of two centrifugal fans each and large ducts up to 31 in. in diameter were necessary. The two new sets were arranged so as to be driven either by water power or by three-phase current motors, the turbines being used in the summer when there was plenty of water, and the motors in the winter. This required the installation of a steam plant, the generator for supplying the ventilating motors being driven by a 300-h.-p. steam engine. Coincident with the installation of the new machines, changes were made so that great flexibility was secured in operating the plant. The fans were arranged so that all could be made to discharge directly into the ducts leading into the tunnel, or could be connected in series so as successively to raise the air pressure.

On account of the already large demands upon the water supply for power, drinking water, and the hydraulic drills, electric drills were adopted for the increase in the driving equipment, instead of Brandt hydraulic drills. For this purpose a steam engine driving a 2,000-volt three-phase current generator was installed in the plant at the tunnel portal and a high tension line strung in the tunnel to a point where a static transformer, which stepped down the current to 250 volts, was installed. The electric drills were first tried on the hardest rock encountered in the small heading and when using about 6 h.-p. were able to advance the heading about 7 ft. per day of 24 hr. This rate did not compare favorably with the progress of the Brandt hydraulic drills which operated in the broader bottom heading, but the difference in the two was not great when the fact that the hydraulic drills used about 20 times the power of the electric drills was figured into the problem. In order further to guard against failure of power during the winter months when water is apt to be scarce, the pumps for supplying the Brandt drills were equipped with a reserve steam engine of 200 h.-p.

The drinking water for the installation was secured from springs in a small creek and stored in a reservoir 377 ft. above the level of the mechanical plant at the north portal. This elevation was sufficient to force the water as far as needed in the tunnel without pumping.

[illegible]uling in the tunnel was done by three types [illegible]motives. In the finished full section near [illegible]al an ordinary steam locomotive was [illegible] operated as far into the tunnel as was [illegible]without seriously fouling the air. Be[illegible]oint and stretching close up to the work in progress electric locomotives were used, the current being supplied from a generator driven by a 200-h.-p. engine. In the heading and the part of the tunnel where work was in progress the hauling was done by small benzine locomotives.

The current for electric lighting was first supplied by a small generator driven by a 20-h.-p. turbine, but as the work progressed another generator, also turbine-driven, was added. These two not proving sufficient toward the end of the work, an additional machine was belted to one of the steam engines that was carrying only a light load. Both arc and incandescent lamps were used.

The entire new equipment was obtained from the dismantled plants used in driving the tunnels on the other new lines.

Installation at the South Portal.—The plant at the south portal, at Mallnitz, was essentially different from the one at the north portal, and much more simple. About 1,500 h.-p. was available in a stream close to the portal and the construction of the necessary work for utilizing it was begun 1904. The dam, canal, and the forebay are entirely built of concrete. From the forebay the 36-in. flanged pipe, 870 ft. long, leads the water to the power house. There are two turbines, each of 615 h.-p. driving 512 KVA. generators. The turbines are of the Pelton type with high pressure oil governors. The generators are direct connected 3-phase current machines, from which the current is transmitted at 6,000 volts over a line about four miles long. Connections are made to the main transmission line for driving an inclined railroad and an elevator up the mountain side. At the mouth of the tunnel the current is stepped down in a transformer room in the power house building.

The difference in conditions at the two portals caused an entirely different development of the ventilating system. There were two different ways of looking at the problem: if the fans were of as low pressure as possible in order to save in the amount of power used, correspondingly large ducts would be required in the tunnel, with the result that the tunnel profile would be restricted; whereas, on the other hand, space might be saved in the tunnel by using smaller ducts, but the amount of power used would naturally be larger. The limited amount of water power available on the north side prompted the use of the former of these two solutions, while on the south side where power was plentiful and cheap the second solution was considered the better. Moreover, the plant at the north portal had to supply fresh air for a length of tunnel of about 6 km., whereas that of the south portal supplied only 2½ km. At the north portal there are over 3,000 ft. of ducts with a diameter of 800 mm., and others of 750, 700 and 500 mm., while on the south side all of the ducts are 500 mm. in diameter.

Brandt hydraulically operated drills were used entirely on the south side of the tunnel. The pumps for supplying the water were driven by three-phase current motors, three in number, all of them being belted to one main shaft which drives the pumps through sets of gears. The haulage in the tunnel and from the south portal was done entirely with electric locomotives which together with the necessary generators, transformers and transmission line equipment, were brought over to the Tauern tunnel after the completion of the Karawanken Tunnel.

The increase in the size of the installation at the north portal was a difficult matter, and the method of making the change was worked out so as not to delay the work in the tunnel. The excavation was carried on by two shifts, each working 8 hr., the one during the day and the other during the night, leaving 4-hr. periods of rest between the two shifts. The change of the shifts, putting the night men on days and vice versa was done every second Sunday and the work was then allowed to lie idle for 24 hr., from Sunday morning to Monday morning. It was planned to make the necessary changes on one of these Sundays and to have the new installation in working order in time for the day shift Monday morning. The work consisted in tearing out part of the large ventilating duct, the removal of the concrete drains from the high pressure pumps, changing the position of the coolers for the ventilating system and the connections between the pressure pumps and the wells, the installation of the connections for the new fans and the various valves, the setting of the new machines and the changing of the positions of the old ones, and the installation of measuring instruments in the ventilating ducts. All of the work that it was possible to do before disturbing the old equipment was finished before the night shift left the tunnel at 6 o'clock Sunday morning. At that time the entire plant was shut down and the work of removing the old structure commenced, the order and method of so-doing being determined beforehand. The changes were made without accident and the new installation put under full load experimentally at 20 minutes before 4 o'clock on Monday morning, 20 minutes ahead of the time determined for the completion of the work.

The installations were described in a paper by Karl Brabbée before the Society of Austrian Engineers and Architects, from which these notes have been taken.

A Mine Draining Plant in England.

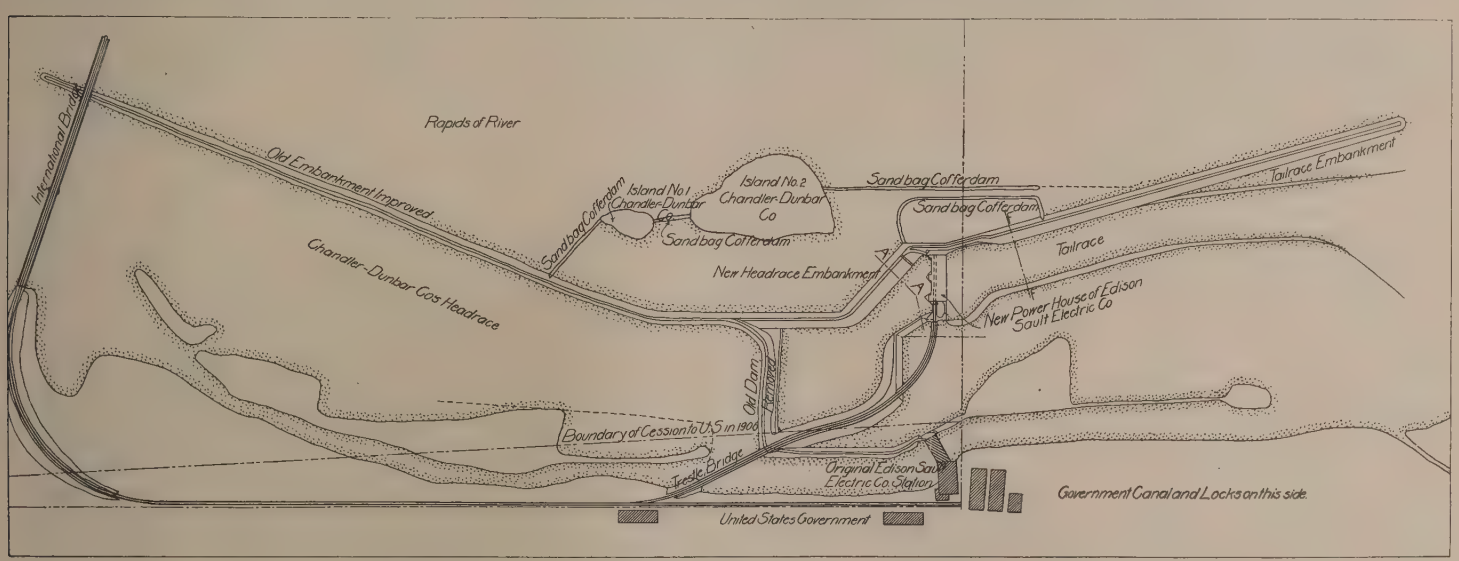
An unwatering plant that possessed some interesting features was installed last year at the Lindal Moor iron mines, near Ulverston, England. The mines were abandoned about four years ago, partly because the plant then in operation could not cope with the water, which at times rushed in at the maximum rate of 7,000 gal. per minute, the dry-weather flow being 4,000 gal. per minute. When pumping ceased the mines rapidly became flooded. The shafts available for pumping purposes were all so small as to make the plant design difficult. The plan adopted was to use electrically-driven, high-lift centrifugal pumps, so arranged that the motors and pumps could be lowered down the shafts as the water receded. A power plant consisting of three steam turbo-alternators was especially erected for the work near the top of the shafts, and supplied three-phase alternating current at 3,300 volts. The shafts at the Diamond pit were vertical, measuring 6 ft. square, and in them two pumping outfits were installed, capable of raising 1,000 gal. per minute against a total head of 680 ft., the motors having an output of 315 h.p. at 1,480 r.p.m. The pumps were three-stage, and the entire apparatus was enclosed in a structural iron frame. The weight of each set, including the suspension cable, electric cable and its column of water was 22 tons. At the Berkune pit, the shafts, which were also vertical, measured 5 ft. 3 in. by 3 ft. 5 in., and the pumps were of the five-stage type, each delivering a maximum of 1,000 gal. per minute against a head of 540 ft. The Lowfield shafts were inclined at an angle of 43°, the pumps in them each designed to deliver 4,000 gal. per minute against a head of 395 ft. To permit rapid operation some of the pumps were arranged so that only some of the impellers were used while the heads were low, and thus discharged nearly 200 per cent. of their normal output. The pumps worked in series when necessary to overcome the high heads. The equipment was described in "Engineering," from which these notes have been taken.

The Hydro-Electric Development in the St. Mary's River at Sault Ste. Marie, Mich.

The Edison Sault Electric Co., of Sault Ste. Marie, Mich., a lessee of water rights from the Chandler-Dunbar Water Power Co., of that place, has recently placed in service a low-head hydro-electric generating station built in the rapids at the head of the St. Mary's River. The latter is the outlet of Lake Superior, and forms the international boundary between Canada and the United States. The development is on the American side, immediately off-shore from the government ship canal and two locks, and about 2,000 ft. downstream from the international railroad bridge over the river. The rapids in the river introduce a fall of about 20 ft. from the railroad bridge to a point 1,800 ft. below the power station, their total length being about three-quarters of a mile. Under present conditions the development renders 16 to 17 ft. of this head normally available, while 3 to 4 ft. additional head could be secured by the acquisition of additional rights below the station. The entire flow of water over the American side of the rapids, with the exception of the small quantity required to supply the two government locks can be utilized for power development.

The power company has an existing hydro-electric station 300 ft. in-shore from the new station. The equipment of this original station is antiquated, and as the land on which the latter is situated was recently ceded to the government by the company, the old station is to be abandoned. The government contemplates the widening of the ship canal and the construction of a large new lock on this recently acquired land and on other land immediately downstream from it. The in-shore end of the new power house is 250 ft. from the boundary line of the government land, the original intention being to build a paper mill on this intermediate site. As the canal and lock works may eventually be still farther extended toward the river, however, this strip of land will not be developed. In fact, to provide for possible further extensions of navigation facilities, the owners desired to construct the power house the width of one canal lock further from shore, but the necessary permission, though approved by the United States Engineers, was overruled by the Department of Justice on account of a pending suit brought by the Lake Superior Corporation in the name of the United States, this suit being conducted by the attorneys of the Lake Superior Corporation. The suit has been decided by both the United States District Court and the United States Court of Appeals in favor of the Chandler-Dunbar Co., so it is now contemplated that the power house may be built out to the international boundary line, about 1,350 ft. beyond the existing off-shore end. The present installation has therefore been designed on the basis that the ultimate station will have wheel capacity sufficient to utilize practically the entire flow of the American side of the rapids, and an equal waste-weir capacity, available when the wheels are shut down.

A head-race, about half a mile in length, was provided for the original station by constructing an embankment down-stream from the international bridge, and 250 to 400 ft. from the existing shore line. The general location of this head-race, as well as its relation to the new works, is shown in the accompanying general plan of the latter. This original embankment was built with the expectation that an off-shore development would eventually be undertaken, and a dam was accordingly built across the head-race 400 ft. above the old station, with a narrower head-race continued to that station from the dam. This dam has been removed and a forebay for the new station provided by extending the head-race between two embankments as shown in the accompanying general plan of the development.



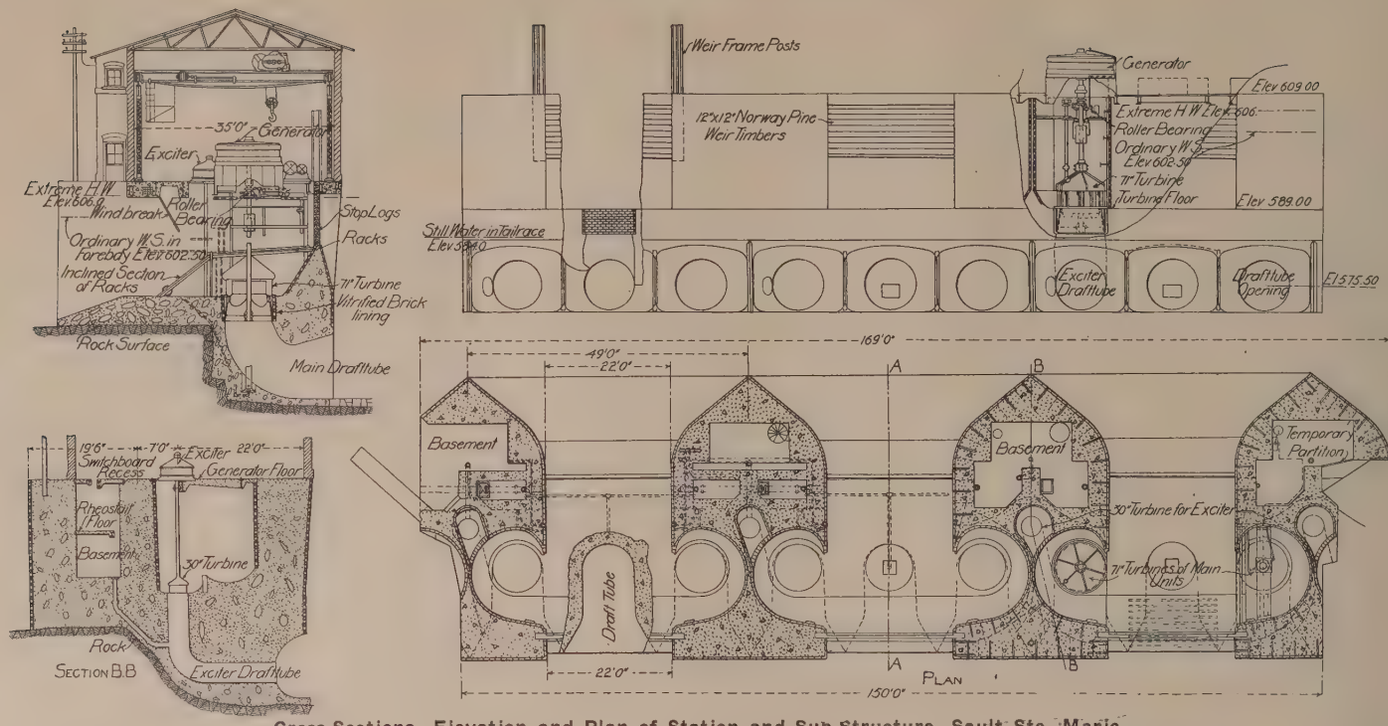
General Plan of the Water Power Development at Saulte Ste. Marie, Mich.

The original head-race embankment was a rock, gravel, clay and sand fill, which has been raised and strengthened with material from the excavation for the station building and for the tail-race leading from the latter. The new embankments which form the forebay of the station are also earth and rock fills, protected with dry stone walls, and adjacent to the building with a 12-in. face of concrete. A tail-race is extended about 1,100 ft. downstream from the station building. This race was built partly in excavation and partly between two embankments. The embankment on the river side of it is a rock, gravel, clay and sand fill similar to the original embankment of the head-race, which has stood for 15 years and is practically water tight. Various sections of these different embankments are shown in one of the accompanying illustrations.

Bed rock at the site is overlaid by 8 to 10 ft. of gravel and boulder deposits, with intervening layers of clay. In general, the embankments were built on this bed of gravel and boulders, although on the forebay side of the embankments the rock was stripped back 10 to 12 ft. from the face of the embankment slope. Where the 12-in. concrete facing was used, it was laid against dry stone walls and bonded into the latter with strips of ⅛x2-in. band iron. The head-race embankments ordinarily have a head of 18 ft. against them, but show practically no leakage. The normal head on the tail-race embankment varies from 4 to 6 ft. at the station building, to about 1 ft. at the downstream end.

The power station building has a monolithic concrete substructure, built on bed rock, and a brick superstructure. The portion of the substructure that has been completed is 49x169 ft. in plan, providing space for nine main water-wheel units. It is arranged, however, so it can readily be extended at either end. The brick superstructure has been erected over two-thirds of this substructure, that is, to cover the space for six main units. It is built with temporary ends, in order that it may also be extended in either direction. Two of the main units have already been placed in service, a third is being installed and the other three will be acquired as needed. These units each consist of a 60-cycle, 3-phase, revolving-field, 450-kw., 4,000-volt, General Electric umbrella-type generator, direct connected by a vertical shaft to a 71-in., 750-h.-p. special vertical Samson turbine, operating at 100 r.p.m. Each unit has four steady bearings, one each above and below the generator and above and below the turbine. A roller thrust bearing just below the generator is supported by an I-beam girder, and carries the entire vertical load of the revolving element and wheel. This roller bearing is fed with oil by gravity and has thus far proved very satisfactory in service. The upper steady bearings are also supplied with oil by gravity, the lower ones being of wood and submerged. For the middle wheel of each group of three, provision has been made for a hydraulic step bearing instead of the roller bearing, if found more desirable.

The arrangement of the main units is shown in the accompanying plan and cross-sectional elevations of the substructure. Three water wheels are supplied from each penstock opening that leads into the building from the forebay. These penstock openings are 22 ft. in the clear and have a free water surface at the top. The heavy concrete piers which separate the adjacent penstocks have cutwaters carefully molded to reduce the disturbance of approach to a minimum, while their bottoms are also sloped at the entrance to secure the same result. One main water wheel is placed on the center line of each penstock, with one of the other two wheels of each group of three in a pit in the pier on each side of the penstock. The sides of these pits are built to deliver the water to the whole periphery of the wheels in them with the smallest possible frictional loss of head. The draft tubes



Cross-Sections, Elevation and Plan of Station and Sub-Structure, Sault Ste. Marie.

are formed in the concrete, and are designed so the water is delivered quietly from the units. Either of the side units may be shut off from the balance of the penstock by stop planks across the entrance to its recess, while the whole penstock may be closed by a floating bulkhead across the opening.

Each three main units are provided with an exciter unit consisting of a 75-kw., direct-current, umbrella-type generator, direct connected to a 30-in. vertical Samson turbine. The water wheel for each exciter is in a separate pit in the pier on one side of the penstock for the group of which it is a part. This chamber is connected with one of the main wheel pits, and is supplied through the latter with water from the penstock. In order to reduce the friction head, the pit for the wheel of each exciter unit is carefully located in reference to the chamber for the wheel of the main unit, and its sides are molded so the water is delivered to the wheel with little loss of head.

Although the low speed of the wheels necessitated larger-sized units than are usual, the arrangement of the wheels more than compensates for the increase in the width of the building that otherwise would have been occasioned. Furthermore, it permitted a rigid requirement of the government for waste openings to be met readily. This requirement stipulated that provisions must be made to pass through the building at such time as the wheels in any penstock are shut down the same quantity of water that would be carried over a section of the river of the width of the penstock. This was accomplished by building in the upper part of the downstream side of the substructure, a wasteway opening for each penstock, the openings being closed normally with 12x12-in. stop logs.

Each wasteway opening is 22 ft. in width, the same as the penstock opening. The lower edge is a weir, with its crest at such an elevation above the bottom of the penstock that when the opening is unobstructed the discharge over the weir will be equal to that of 49 linear ft. of river cross-section, 49 ft. being the distance between the center lines of the penstock piers. A groove for the stop logs is built into the concrete at each end of the opening. The stop logs are handled by a 15-ton motor-driven traveling crane, carried, in the superstructure, by a runway on steel columns. In order that the waste weirs could be conveniently placed in the sides of the substructure, and the stop logs closing them still be accessible to the crane, the downstream face of the substructure was built on a slight outward batter, so the floor of the superstructure cantilevers over that face.

A rack for intercepting and diverting from the wheels all floating and frazil ice and other debris is placed across each penstock. The lower section of this rack makes an angle of about 45 deg. with the horizontal, and extends from the bottom of the penstock to above the level of the top of the wheel casing. The top section of the rack is nearly horizontal and extends over the casing of the middle wheel, from the top of the inclined section to the waste weir. A vertical rack is placed across the entrances to the side wheel pits, above the inclined rack, to protect the wheels in these pits. By opening the upper part of the waste weir a strong current can be created near the surface of the water, which it is expected, will, to a very considerable extent, carry with it through the center of the penstock, the floating ice and prevent the stoppage of the side wheels, and the closing of the racks below.

The water wheels are each regulated by a Type D Lombard governor mounted on the floor over the wheel pit. Each governor is driven by a bevel gear on the shaft of the revolving element of the unit which it controls. The gate shaft of the water wheels is operated by the governor through a wire-cable rope drive.

The upstream ends of the piers between the penstocks are hollow, and provide basement space for oil storage, rheostats and a toilet. A spiral

Rapids from End of Tailrace Embankment.

Electric Locomotive Used in Construction.

Station Building from Upstream Side.

Station Building from Downstream Side.

iron stairway leads down into each of these small basements, which are drained by 8-in. pipes connected to the draft tubes of the exciter units. The rheostats are placed on mezzanine galleries in order to protect them from possible dampness in the bottom of the basements.

A four-panel switchboard in a wire tower recess on the upstream side of the building is provided for each group of three generators and their exciter. Lightning arresters and static discharges are placed in each wire tower, from which transmission lines lead out of the station. Current is transmitted at 4,000 volts and is stepped down to 220 volts for commercial lighting and is transformed to 500 volts direct current for power.

Construction.—The construction of the development was all handled under considerable hazard, and parts of it with serious difficulties. The sites of the forebay, the station building and the tail race were all covered with water from 2 to 6 ft. deep, which was flowing at a velocity of from 7 to 15 miles an hour. Two islands, that occur off-shore and just upstream from the station building, broke the force of the current over the rapids, so heavy sand-bag cofferdams could be built from the existing head-race embankment to these islands, and downstream from the latter, to a point well below the station building. The fall of the river was sufficient to enable all of the site, except about 850 ft. of the 1,100-ft. tail-race embankment, to be unwatered, and the construction handled in the dry. Such water as leaked through the cofferdams was removed by electrically-operated centrifugal pumps. The excavation of the tail-race was also carried on in the dry, as the construction of the embankment on the river side of it was advanced.

The spoil from the tail-race excavation was largely sand, clay, gravel and boulders, while the excavation for the power house was nearly all in rock. Practically all the material taken from these excavations was used in strengthening the existing head-race embankments, and in building the new embankments for both the head and tail-races. It was moved in 1½-yd. cars running on 24-in. gauge tracks laid from the excavations up to the grade of the embankments. These cars were handled by home-made electric locomotives, which operated with great satisfaction in doing this work, and also in delivering construction materials to the building. Each locomotive consisted simply of a four-wheel truck carrying a 30-h.-p. Northern motor, equipped with an ordinary street-car controller and the necessary starting resistances. Power was obtained from an overhead trolley wire supplied with direct current at 500 volts from the existing power station. The motor was designed to operate at 450 r.p.m., but it was geared to both axles of the truck with sprocket wheels and chains which reduced the speed to satisfactory limits. As thus equipped, the locomotive could readily haul five loaded 1½-yd. cars up a 6½ per cent. grade. It could also handle a train of cars, either on a grade or on the level, with considerable speed, thus enabling a large output to be maintained. One of the chief features in favor of it, however, was that it only weighed about three tons, so no heavy concentrated loads were brought on the tracks. The latter were used at first, in fact, with the cars drawn by horses. They had 20-lb. rails and 4x6-in. ties, which permitted them to be shifted readily, and required very little work to put them in running shape after being shifted. The trolley wire brackets were carried on overhanging arms on uprights fastened to the end of long ties, so the wire was moved with the track, without difficulty.

The concrete in the substructure of the station building was made in two different mixtures, depending on the location; one, in the proportion of 1 part cement, 2½ parts sand and 5 parts broken stone, and the other 1:3:6 of cement, sand and stone. In places where massive concrete was required, boulders up to the size of an ordinary bucket were imbedded in the concrete. Alpena Portland cement, river sand and crushed stone from the excavation for the station building, mixed with an equal quantity of crushed drift boulders, were employed.

An electrically-driven Smith mixer was erected in a tower close to the site, where it could be supplied with materials conveniently. The sand was brought to the lower end of the head-race site in barges, from which it was delivered to the mixer in dump cars hauled by one of the electric locomotives. The stone from the excavation was broken in an electrically-driven crusher set up at the work, and was delivered to the mixer in cars. The cars were hoisted by

Views of Tailrace End of Draft Tubes during Construction.

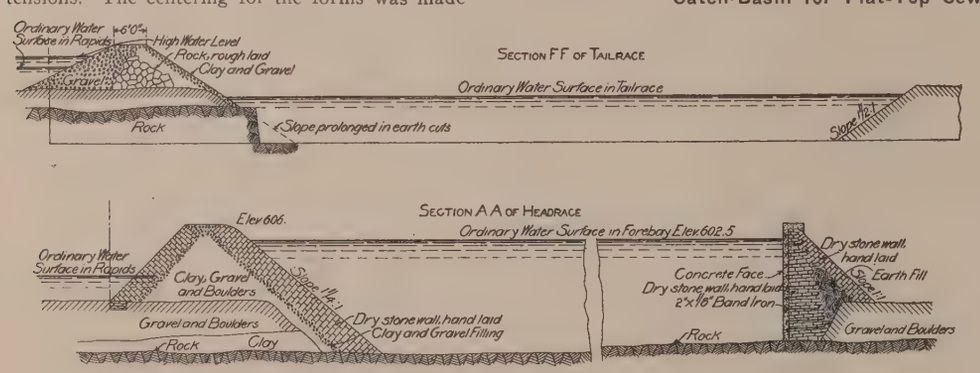
an elevator to a platform around the charging hoppers over the mixer. The latter discharged into side-tip buckets handled by derricks directly to place, or to stationary hoppers which supplied chutes leading down into the work.

Customary wooden forms for the concrete were almost entirely replaced by a single course of paving brick placed as a veneer to the concrete. The brick were laid in cement mortar and were built up to conform to the outlines of the concrete by using templates. The thin brick walls were carried up about 3 ft. ahead of the concrete, thus giving the mortar time to set before any load was brought on them. The brickwork was tied into the concrete with iron rods, placed at various intervals on different parts of the work, depending on the conditions; where tension might occur during construction it was reinforced by two strands of ⅛-in. telegraph wire laid in every fourth joint. It was found the brick forms handled in this manner were much cheaper and more satisfactory than wooden forms. The saving in their favor was particularly great in connection with the intricate curves and surface on the piers and in the wheel pits. One of the accompanying views of the draft tubes under construction shows relatively how the brick was carried up ahead of the concrete work.

Owing to the shape of the draft tubes the forms for them were first built up entirely in wood. The curves and the varying cross sections of these tubes made this form work very difficult and expensive in places, but the forms were built so as to be of service for further extensions. The centering for the forms was made of 2x12-in. plank carefully cut to templates; these centers were lagged with ½x2-in tongue and grooved flooring, cut and dressed to produce the warped surfaces of the draft tubes. After the first of the latter had been built with forms made in this manner it was found that equally good results could be secured at much less expense by replacing portions of the wooden lagging with wire-screen cloth covered with heavy canvass. Accordingly, the balance of the main draft tubes and those for the exciters were built with forms partly covered in that way.

The construction of the tail-race embankment was the most hazardous part of the whole project, so far as construction is concerned. The water over the site of the embankment was from 5 to 6 ft. deep and had a current of at least 15 miles an hour in places. Notwithstanding these conditions, the embankment was completed without much difficulty. This embankment is a continuation of the outer embankment of the forebay, so the track used on the latter could be extended out on it as the work advanced. The largest stones and boulders from the excavation were first delivered in the dump cars and dropped over the end of the track until the force of the stream was broken. Many of these stones and boulders, having 1 cu. yd. or more of volume, were carried away before the desired results could be obtained. As fast as the current was reduced sufficiently, smaller stones were brought out and dumped, and finally the rear or tail-race side was finished off with gravel and sand. The embankment has a minimum width of 6 ft.; the slope on the tail-race side was made 1½ to 1, and that on the river side, 2 to 1. Although little clay was used for this embankment, it is practically water tight, and after having been in place for a year and a half shows no evidence of weakness.

Mr. Alex. Dow, of Detroit, Mich., is president and general manager of the Edison Sault Electric Co. The other officers are all of Sault Ste. Marie and are as follows: Mr. Wm. Chandler, vice-president; Mr. D. B. South, secretary; Mr. S. G. Carlton, treasurer, and Mr. S. E. Peel, superintendent. Gardner S. Williams, of Ann Arbor, Mich., professor of civil engineering at the University of Michigan, as consulting engineer to the company, prepared the plans for the development and supervised the execution. Mr. Arthur Adams was resident engineer in charge for Professor Williams. The masonry construction, the excavation and the embankments were handled on a percentage basis by the MacArthur Bros. Co., of Chicago. The hydraulic apparatus, which embraces several special features designed for this plant by Professor Williams, was built by James Leffel & Co., of Springfield, Ohio, and the electrical equipment by the General Electric Co. The Standard Roller Bearing Co., of Philadelphia, furnished the roller bearings on the generators. All of the equipment and apparatus was installed by the employes of the Edison Sault Electric Co., working under the direction of the engineer.



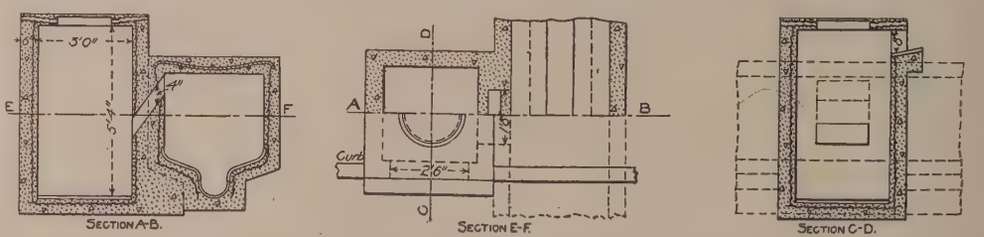
Sections of Headrace and Tailrace Channels, Sault Ste. Marie.

A Steam Motor Car has recently been put in service and others are being built by the Intercolonial Railway of Canada. In general appearance these cars resemble the combination passenger and baggage cars often seen in this country but the space reserved for baggage in such cars in this motor car is occupied by a locomotive boiler and coal bunkers. The locomotive is four-wheeled, and its wheels take the place of the regular passenger car truck at one end of the car. The car is 66 ft. long over the end sills and has a seating capacity for 52 persons. The locomotive is rated at about 200 h.-p. and is designed to give a speed of 25 miles per hour on a 1 per cent. grade. The cars are arranged to run either end first. Besides the boiler room and the main passenger section there is a baggage room and a smoking compartment.

Reinforced Concrete Sewers in Staten Island.

The Borough of Richmond, of the City of New York, includes all of Staten Island, which has a triangular form, with a maximum width and length of 7 and 14 miles, respectively. Its area is about 57¼ square miles. The island is hilly inland, but the shore land slopes back gradually for some distance, and is in many cases only a few feet above the elevation of mean high water. The hills are, in general, wooded or overgrown with brush and practically unsettled, but around the shore there are many villages. The total population is about 77,000. For many years the increase of population on the island has been very slow, but since the island became a borough of New York a more rapid increase has been noted, and it is considered probable that eventually the greater part will be well built up. The sewers of the borough are being designed, therefore, to meet the expected future conditions.

About 35 sewerage districts have been laid out, covering the entire island, but some of these districts are as yet only tentatively fixed. The districting has, of course, been determined by the topography; in general, it is expected that one main trunk sewer will serve as an outlet for each district. In some districts there are old separate sewers, and these, when in good condition, have been preserved, but the new sewers are all designed on the combined system. Up to the present time four main trunk sewers have been completed and two more are now under construction. Of these, three are interesting, on account of the somewhat unusual sections necessitated by the slight difference in elevation between the general ground level near the outlet and mean high water level, and the fact that the law requires all house sewage to be discharged beyond the pier-head line. Though a detailed topographical map of the borough, which will serve as a basis for designing street and sewerage systems, is being prepared, by methods described in The Engineering Record of July 20, 1907, this work is still in an incomplete state, and in designing the sewers it is necessary in many cases to make surveys to determine the most advantageous street grades and elevations of inlets and manhole tops as well as to fix the sewer grades.

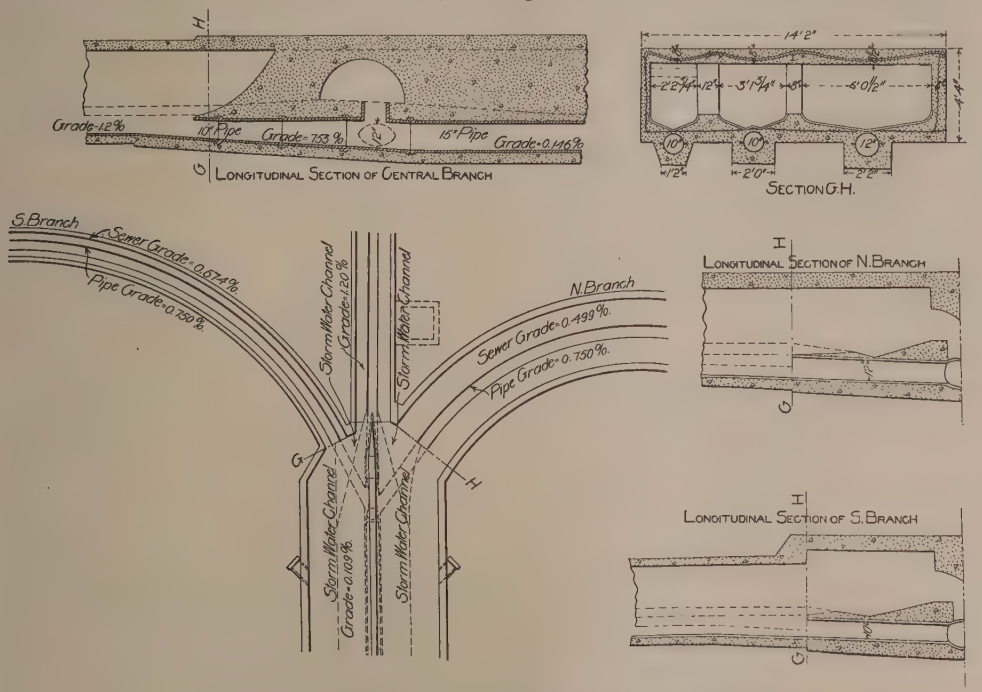


Catch-Basin for Flat-Top Sewers in Staten Island.

In order to avoid the expense of carrying the heavy construction of the main trunk sewers out to the pier-head line the expedient has been generally adopted of discharging the storm-water flow at the bulkhead line and carrying the dry-weather flow out the required distance through a cast-iron pipe supported on piles braced for rigidity. Where the difference in elevation between mean high water and the ground level requires a flat-top section, the invert is generally made nearly flat, also, except that in the center a depressed channel is provided for the dry-weather flow. The grade of the storm-water overflow is arranged so that sewage will not enter it, except during rainy weather, when the sewage will be so diluted as to become inoffensive.

Trunk Sewer for District 6 A.—The trunk sewer for Sewer District 6 A, in the Fort Wadsworth section of the Borough, covering an area of about 366 acres, is now under construction.

The outlet end of the main sewer is at the bulkhead line, or at Sta. 5+10, according to the survey; from this point to Sta. 8 the sewer has, except for a few feet at the outlet end, in general a semi-circular invert 6½ ft. in diameter, lined with vitrified brick, and a flat reinforced concrete slab roof, the under surface of which is 2 ft. 8 in. above the springing line of the inverted arch. The side walls are vertical and are reinforced with No. 10 expanded metal, as indicated on an accompanying cross section. The roof slab is 8 in. thick and is reinforced with ¾-in. concrete, as shown in an accompanying cross-section, and is 24 ft. deep from top to bottom. The difference in elevation between the entering and leaving inverts is 8½ ft. A 20-in. cast-iron bypass pipe, arranged as shown in the drawing, is provided to handle the dry-weather flow, which is thus led quietly from one sewer to the other without the spattering which would prevail if the bypass was not provided. The flow through the bypass also forms a water cushion at the bottom of the manhole and breaks the heavy impact of the storm-water flow. The manhole is designed so that when the sewers are flowing two-thirds full or more a whirlpool will be formed in the vertical shaft, thus protecting the walls of the latter from the rush of incoming water. The bottom of the manhole is paved with trap rock blocks and has a sharp slope, as shown, to insure a good initial velocity of flow. The regular manholes, which are placed at changes of grade and at intervals of about 200 ft., where the grade is uniform, are built of concrete up to the level of the springing line of the sewer arch and above that point of brick.



Junction at Upper End of Outlet Sewer, District 2A.

To carry the dry weather flow the required distance from the end of the main sewer about 220 ft. of 20-in. cast-iron pipe is provided. Beginning at a point 22 ft. above the end of the main sewer the form of the invert is changed from semi-circular to a form designed to fit and enclose the circular end of the cast-iron pipe. This change is made in a distance of about 15 ft. The cast-iron pipe extends into the main sewer 7 ft. The pipe is carried 14 ft. beyond the end of the large sewer on a concrete apron, which consists of a 20-in. concrete slab reinforced near its upper and lower surfaces with expanded metal and carried by side and end walls, which enclose the supporting material and extend down 5¼ ft. below the top of the apron.

Beyond the apron the pipe is supported by pile bents 12 ft. on centers, two piles to a bent 2½ ft. on centers. Transverse caps, 10x12 in., slightly cut to fit the pipes, support the latter, which are securely strapped in place with galvanized iron bands. Guard pile bents are placed midway between the supporting bents, the piles of these bents being 4½ ft. on centers transversely and securely braced, both longitudinally and transversely.

All the excavation for this sewer is being done by hand, but the methods of handling the spoil vary somewhat. For the greater part of the outlet sewer the depth of the trench required was in general only a little more than the depth of the sewer. The spoil in this stretch was thrown out by hand and but little sheeting was required. The 3 ft. 10 in. by 5 ft. 9 in. branch, however, for about 700 ft. is 19 to 25 ft. below the street. The construction of this part of the sewer is rendered particularly difficult by the unstable character of the clayey soil and the presence of a double-track street car line in the street

Junction of Sewers above Outlet, District 17 A, Staten Island.

"old style" Johnson bars, both transversely and longitudinally, the former being placed 6 in. on centers and the latter 18 in. on centers. Over the top and on one side of this section of the sewer there is practically no covering material, the land being in general below the level of the roof slab. The sewer is close to the property line, and filling material cannot be placed on the property side; a covering of earth is to be placed on the top of the sewer and the street graded up, and to retain this in place the free wall on the property side has been carried up 8 in. above the top of the roof slab to form a curb. The flat-top section is laid on a grade of 0.823 per cent.

At Sta. 8 there is a reducer and the sewer changes to a circular section, 6 ft. 4 in. in diameter. This section continues to Sta. 15 on a grade of 0.881 per cent., the cover in this distance ranging from 0 to about 13 ft. At Sta. 15 there is a junction of two egg-shaped sewers, 4 ft. 6 in. by 6 ft. 9 in. and 3 ft. 10 in. by 5 ft. 9 in. These enter the circular outlet sewer on curves of 34 ft. and 36 ft. radii, respectively, and extend at right angles to the line of the outlet sewer in opposite directions. Just beyond this junction the 4 ft. 6 in. by 6 ft. 9 in. sewer enters a drop manhole, which was designed to reduce the steep grade and consequent excessive velocity of flow. These branches run back into the district to collect the flow from vitrified pipe and small reinforced concrete laterals. In design these egg-shaped sewers present no unusual features; the invert is in all cases lined with vitrified brick; in smaller sizes 1-3 split vitrified pipe forms the lowest part of the invert. The arch ring in all sizes is reinforced with No. 10 expanded metal. House connections are provided on all branches, placed about 20 ft. on centers on each side of the sewer.

The drop manhole is built of brick and con-

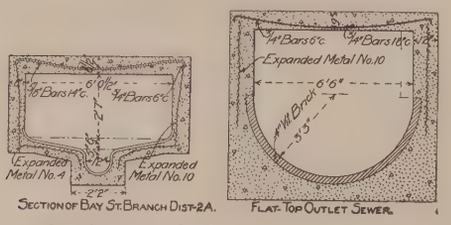
Where the work is in progress the cars are operated over a single track, the other having been taken up to make room for the trench. Two-by-ten-in. plain plank sheeting in 14-ft. lengths is used, two lengths being necessary to reach the bottom of the trench. Waling pieces are placed about 5 ft. on centers and are heavily braced to withstand the excessive pressure due to the passage of street cars and the weight of the earth. The sheeting is driven with a 100-lb

McKiernan steam driver. The ground water which seeps into the trench is carried away by two lines of 4-in. drain tile, one line of each side of the main sewer. These drain lines are extended as the work progresses and reach from the present point of construction to the outlet of the main sewer.

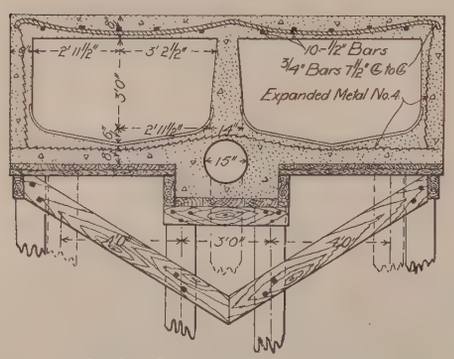
The spoil is shoveled into Hayward buckets, which are hoisted by a cableway and delivered over the completed sewer as back-fill. The cableway, which is 300 ft. long, was supplied by the Carson Trenching Machine Co. It is operated with a Lidgerwood engine and boiler mounted on a four-wheel truck platform, which also carries the A-frame headtower. The truck wheels run on plank runways.

The concrete, which is a 1:2:5 mixture of Phœnix Portland cement, Cow Bay sand and crushed trap rock, is mixed by hand on a platform spanning the trench and is delivered to place in buckets.

For the egg-shaped sewer now under construction wooden forms of the usual type are used for the invert and steel centers, supplied by the Blaw Collapsible Steel Centering Co., are used for the arch ring. The steel centers are



Sections of Staten Island Sewers.



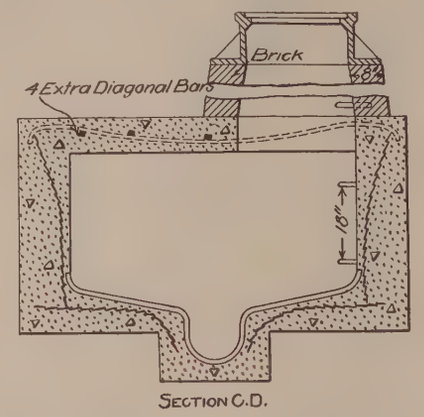
Outlet Sewer, District 2 A.

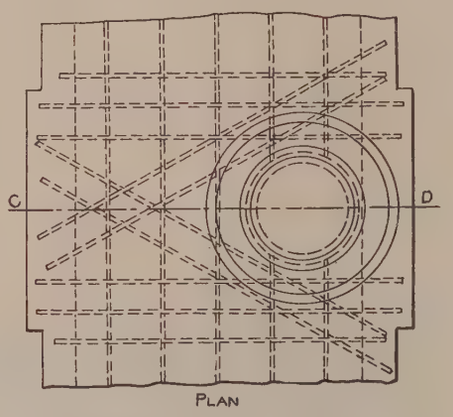
greased slightly with linseed oil to prevent the adhesion of the concrete, and a very smooth surface has been secured by their use. They are drawn in 25-ft. sections, made up of ten 2½ lengths.

Trunk Sewer for District 2 A.—District 2 A, in the Tompkinsville section of the island, comprises about 155 acres. A great part of this area is very hilly, so much so indeed that 11 drop manholes are required in 1,500 ft. of sewer, the grade of the sewer being designed to limit the velocity of flow to 12 ft. per second when flowing full. On the other hand, Bay street, an important street in this district, paralleling the water front, is very low, being for some distance only 5 to 9 ft. above mean high water.

At the junction of Elizabeth and Bay streets two main branch sewers coming from opposite directions in Bay street meet another branch coming down from the hills in Elizabeth street, and the three join and are carried on in Elizabeth street to the bulkhead line, a distance of about 600 ft., by the main outlet sewer. Each branch sewer has a flat-top section, with vertical sides, and the invert sides slope gently toward the center, where a depressed channel is provided to carry the dry-weather flow. The section of the larger branch sewer in Bay street, which is shown in an accompanying illustration, is typical of the section of the other branches, the approximate sizes of which are shown in the section GH, taken at the junction point.

The outlet sewer has a twin-branch flat-top section and a 15-in. pipe conduit for the dry-weather flow. The storm-water section of each branch is 5 ft. 11 in. wide and about 3 ft. high, though both width and height vary slightly, as is shown in the cross section. The roof slab is reinforced both transversely and longitudinally with steel bars of the sizes and spacing indicated. The outside walls and floor are reinforced with expanded metal. The inverts are surfaced with a 1-in. coat of artificial stone, composed of equal parts of cement and trap rock





Manhole on Flat-Top Sewer.

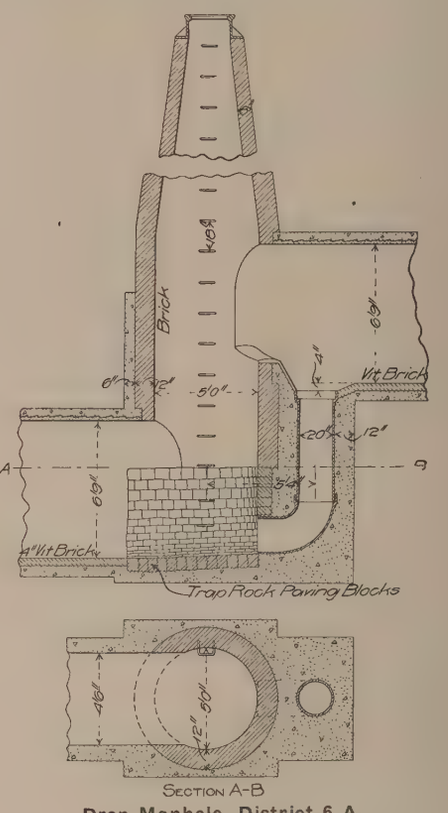
screenings, applied and troweled to a smooth surface as soon as the rough work has set sufficiently to allow it. Pile foundations of the form shown are provided throughout the whole length of the outlet sewer.

About 300 ft. from the bulkhead line the sewer is crossed nearly at right angles by the double-track line of the Staten Island Rapid Transit R. R. The top of the roof slab is about 16 in. below the base of the rails, and the sewer is designed to carry the weight of the tracks and the live loads on them. The thickness of the roof slab is increased to 14 in., and it is reinforced transversely with ⅞-in. bars, 6 in. center to center, and longitudinally with ¾-in. bars placed in the same relative position as the longitudinal bars in the section illustrated. The thickness of the side walls is also increased. Batter piles are placed on the north side of the sewer under the east-bound track and on the south side of the sewer under the west-bound track to resist the thrust due to braking trains on the track.

The dry-weather flow will be carried from the end of the main sewer to a point 439 ft. beyond by a 16-in. cast-iron pipe line, supported on piles in the same manner as has been described in connection with the trunk sewer for District 6 A.

Owing to the low level of the main outlet section of this sewer a large part of the construction work has to be carried on during periods of low tide. The excavation was made by hand, the trench being made wide enough so that sheeting was not required. The piles were driven with considerable difficulty, owing to the presence of a large amount of old cribbing and riprap; the penetration, for the same reason, varied greatly, the maximum and minimum being about 42 and 12 ft., respectively. But little concrete has been placed as yet in connection with this work; Pennsylvania Portland cement is used with sand and trap rock in the same proportions as for the Fort Wadsworth sewer.

Trunk Sewer for District 17 A.—District 17 A, in the Elm Park section of the Borough, is served by three sewers, which are brought to a junction just above the outlet, to collect the house flow, which is taken out in the Kill von



Drop Manhole, District 6 A.

Kull by a 12-in. cast-iron pipe, supported on piles in the usual manner. The three main branch sewers are of the flat-top and depressed-channel type, very similar to those under construction in Tompkinsville, and the junction is much like the one to be built at Elizabeth and Bay streets.

The outlet is of the twin-branch flat-top sort, each branch being about 2½x6 ft. It is crossed just below the junction point by a double-track street car line. The cover at this point is practically zero, and the rails are embedded in the rail-top of the sewer, so that the rail heads only 5 in. above the top of the slab. The outlet was constructed without interrupting traffic on the car lines.

The depressed channels of the sewers in this section are lined with sections of vitrified half pipe. This proved an aid to construction, for the pipe, with its bedding of concrete, was laid a little way ahead of the rest of the work all the time and served to drain the trench. The forms used were wooden, of the usual type. Building paper was laid over the top of the flat-top forms to give a smooth finish; this made it possible to use rough lumber and still secure satisfactory results. Phœnix and Atlas cement was used and Johnson "new style" bars. The concrete was mixed by hand.

To meet the same conditions that necessitate

flat-top sewers special catch basins and manholes have been designed. The manholes are built in general of brick, and the basins of concrete reinforced with expanded metal. Illustrations showing sections of a manhole and basin are given.

The engineering work for construction in the Borough of Richmond is under the general direction of Mr. Louis L. Tribus, Commissioner of Public Works and consulting engineer, and Mr. Theodor S. Oxholm, engineer in charge. Mr. L. W. Freeman, assistant engineer, has direct supervision of sewer work. The designs for the sewers described were prepared by Mr. Victor H. Richelt, assistant engineer. Messrs. Joseph Johnson's Sons, P. Hart & Sons and James Conley are the contractors for the sewers in Districts 6 A, 2 A and 17 A, respectively.

Foreshore Improvements at the Chalk Cliffs, England.

Foreshore improvements have been completed at Brighton, England, to check the erosion of the local chalk cliffs. The cliffs are 75 to 125 ft. high and have been cut back during the past eleven years at the rate of about a yard per year, according to "The Engineer," London. A highway and several public buildings on the cliffs were endangered in consequence. The foreshore consists of practically bare chalk, but there was apparently plenty of traveling material and a good supply of sand just below low-water mark. Accordingly it was decided to erect a series of groins perpendicular to the face of the cliff and extending to the low-water line to intercept the moving shingle and cause the formation of a protective covering over the chalk. They are made of 16-in. square columns between which are 6-in. concrete slabs. The columns are 5½ ft. on centers for the first 200 ft. from the face of the cliff and 7 ft. for the remainder of the distance to the low-water line. Their clear height above the chalk increases from 2½ ft. near the low-water mark to 8 ft. near the cliff. Grooves are formed in them to receive the slabs which are dropped into place and grouted fast. The slabs are formed in units 1 ft. high and not more than two or three units are placed at first; as the shore builds up more will be added. The columns are set in holes in the chalk and where necessary 10x10-in. concrete struts are built for additional support. Messrs. Owens & Case, of Westminster, are the engineers for the work.

THE COAL PRODUCTION in Pennsylvania in 1906 was 200,575,617 short tons, of which 71,282,411 tons was anthracite. This is an increase of 2.3 per cent. over the production in 1905. In mining this coal, there were 557 men killed and 1,212 injured in the anthracite mines, and 477 killed and 1,160 injured in the bituminous mines. In both classes of mines the major cause of accident was falling of the roofs. The State produced 48.4 per cent. of the total coal mined in the country during the year. These figures are furnished by the United States Geological Survey, which states that the rapid growth in the production of bituminous coal during recent years compared with that of anthracite forms one of the most interesting features in the statistics of coal mining. From 1876 to 1880 the average production of soft coal in Pennsylvania was 1.41 times that of anthracite, while from 1901 to 1905 the bituminous production was 4.08 times that of the other. In explanation of this change it is stated that for a number of years anthracite has been practically eliminated as a fuel for manufacturing purposes, and has been used almost entirely for domestic purposes in Eastern states. And now, even for domestic purposes, coke and gas are competing more and more with anthracite in the larger cities and towns.

Tests of Gasoline Engines Using Alcohol.

A brief mention has already been made in these pages of the elaborate tests made by Prof. C. E. Lucke and Mr. S. M. Woodward to determine the behavior of internal combustion engines using both gasoline and alcohol as fuel. The report is a profusely illustrated pamphlet of nearly a hundred pages, giving the details of many tests with eight engines of different types. The information regarding the tests themselves is too complex in its nature to be given satisfactorily in abstract, but some of the general statements in the report and the authors' summary of their conclusions are as follows:

The objects of this investigation may be put under two heads:

First, to determine whether gasoline and kerosene engines can run on alcohol as fuel. This involved the manipulation in making the engines run on alcohol, the measurement of the maximum powers of the engines when using alcohol and other fuels and last the relative consumptions of the different fuels.

Second, to determine the improvements desirable in engines manufactured especially for alcohol.

The engines used were: No. 1, a 15-h.p., 2-cylinder, vertical, 4-cycle gasoline engine; No. 2, a 6-h.p., horizontal, 4-cycle gasoline engine; No. 3 a 6-h.p., horizontal, 4-cycle gasoline engine; No. 4, a 6-h.p., vertical, 4-cycle gasoline engine; No. 5, a 6-h.p., horizontal, 2-cycle kerosene engine; No. 6, a 40-h.p., 4-cylinder automobile gasoline engine; No. 7, a 40-h.p., 4-cylinder automobile gasoline engine; No. 8, a 2-h.p., vertical, 2-cycle marine gasoline engine. The last three, of course, were high-speed engines.

Gasoline and kerosene are most easily examined by their specific gravities but since each is a mixture of numerous lighter and heavier oils, a constant density is not a guarantee that the composition may not change sufficiently to affect the action of the fuel in an engine.

Commercially pure grain or ethyl alcohol is sensibly pure except for the water which may be mixed with it. In this country alcohol is described according to its strength by stating the percentage of absolutely pure alcohol, by volume, which exists in the mixture of alcohol and water. Thus, 90 per cent. alcohol means that if the alcohol present could be separated absolutely pure, its volume would be 90 per cent. of the volume of the actual mixture of alcohol and water.

In France the strength of alcohol is described as in this country, but on the other hand, in Germany the strength is always expressed as percentage of alcohol present by weight.

In the statistics relating to alcohol, issued by the Commissioner of Internal Revenue, quantities are stated in "proof" gallons. A proof gallon contains 50 per cent. alcohol by volume, the remainder of the mixture being water; hence, a quantity of alcohol when stated in proof gallons is expressed by a number just twice as large as it would be if stated in gallons of 100 per cent. alcohol.

The denatured alcohol which may be used in engines in the United States must be prepared as follows, according to the regulations of the Commissioner of Internal Revenue: To 100 volumes of ethyl or grain alcohol of a strength not less than 90 per cent. there must be added either 10 volumes of methyl or wood alcohol and one-half of 1 volume of benzine or 2 volumes of methyl alcohol and one-half of 1 volume of pyridin bases. The substances added to the grain alcohol will probably not be of uniform quality, and hence there will be some variability in the properties of the denatured alcohol which will affect its use as a fuel.

The heat of combustion of the various petroleum oils varies between 19,000 and 21,000 B.t.u. per pound and 20,000 is used as an average value. The experimental value for pure alcohol is about 12,700 B.t.u. per pound.

By the formula for ethyl alcohol, C_2H_5OH, its molecular weight is 46. For the complete combustion of 1 molecule of alcohol the 2 atoms of carbon require 4 atoms of oxygen to form carbon dioxide and the 6 atoms of hydrogen require 2 atoms of oxygen, in addition to the 1 atom present, to form steam, thus making 6 atoms of oxygen in all to be supplied. The weight of the 6 atoms is $6 \times 16 = 96$. Hence complete combustion of 1 lb. of C_2H_5OH requires $96 \div 46 = 2.086$ pounds of oxygen. In 1 lb. of pure dry air there is 0.230 lb. of oxygen, so that the combustion of 1 pound of C_2H_5OH requires $2.086 \div 0.230 = 9.06$ lb. of air, or about 119 cu. ft. of pure air at a temperature of 60° and at sea level. If the alcohol contains water, 1 pound of the alcohol-water mixture requires less air than that stated. If the air is moist, 1 pound of it contains slightly less than 0.230 lb. of oxygen and hence more air would be required. In an actual engine the amount of air is proportioned to the amount of vapor, not by any exact measurement of either, but by trial to secure either the best results in maximum power or in minimum fuel consumption.

As with all substances which liquefy at ordinary temperatures, there is a definite limit to the amount of alcohol vapor which can exist in a cubic foot of space at any given temperature. Assuming the laws for perfect gases to hold, at any given constant temperature the weight of alcohol vapor present in a cubic foot of space is proportional to its vapor pressure and is usually measured or represented by this vapor pressure.

The vapor pressure of saturation increases rapidly with the temperature, and the values as determined by experiment for alcohol and some other substances at various temperatures are given in Table 1.

When different gases or vapors exist simultaneously in the same space, if they have no chemical action on each other, each one acts by itself just as though no other gas were present. But it is to be noted that in such a case the pressure as measured by a barometer column or pressure gauge would be the sum of the separate pressures due to the air and due to the alcohol vapor. If moisture were present it probably would have some effect on the alcohol-vapor pressure, because water and alcohol have a certain affinity for each other.

TABLE 1. VAPOR PRESSURE OF SATURATION FOR VARIOUS LIQUIDS, IN MILLIMETERS OF MERCURY.

Temperature. °C.	Temperature. °F.	Pure Ethyl Alcohol.	Pure Methyl Alcohol.	Water.	Gasoline.
0	32	12	30	5	99
5	41	17	40	7	115
10	50	24	54	9	133
15	59	32	71	13	154
20	68	44	94	17	179
25	77	59	123	24	210
30	86	78	159	32	251
35	95	103	204	42	301
40	104	134	259	55	360
45	113	172	327	71	422
50	122	220	409	92	493
55	131	279	508	117	561
60	140	350	624	149	648
65	149	437	761	187	739

Since alcohol, as used commercially, is always mixed with some proportion of water, a combustible mixture formed by the vaporization of such alcohol may become saturated with water vapor before it is saturated with alcohol and this may retard the complete vaporization of the alcohol. Such a state is more likely to occur if the air originally contains a considerable amount of water vapor—that is, if the relative humidity is high. In such a case a temperature higher than 72° would be necessary to maintain the required amount of alcohol vapor in the mixture.

In order that alcohol may change from a liquid

to a vapor, it must receive a large amount of heat either from the air with which it mixes or from the metal parts of the carbureter with which it comes in contact. The hotter these parts the more quickly the alcohol can absorb the requisite amount of heat. But if the air is too hot there is danger that the mixture of air and alcohol vapor produced may be too rich in alcohol and some of the vapor must remain unburned. Still, if the air be moist, or the alcohol contain water, or the time allowed for vaporization be too short, the temperature of the air must be higher than 72° to form a proper explosive mixture.

Air at any temperature will take up some alcohol vapor, and the higher the temperature the quicker it will take up the amount necessary for the best explosive mixture. In the case of incomplete vaporization, some of the fuel may be carried along as spray, which may or may not be vaporized in the cylinder on the compression stroke. If not, it certainly will be vaporized after the explosion of the rest. It would seem desirable, therefore, to heat considerably the air supplied to an alcohol carbureter. But too much heating of the air will bring about a bad effect on the engine, because it will make the charge hotter at the end of compression, and thus decrease the weight of the charge in the cylinder. The horsepower of the engine, other things being equal, will be decreased in direct proportion as the density of the charge is lowered by this heating, so that heating of the air before carbureting is good for complete vaporization, but bad if carried too far in its effect on power reduction.

The following general conclusions are drawn as a result of the investigations reported in detail above:

(1) Any gasoline engine of the ordinary types can be run on alcohol fuel without any material change in the construction of the engine. The only difficulties likely to be encountered are in starting and in supplying a sufficient quantity of fuel, a quantity which must be considerably greater than the quantity of gasoline required.

(2) When an engine is run on alcohol its operation is less noisy than when run on gasoline, its maximum power is usually materially higher than it is on gasoline and there is no danger of any injurious hammering with alcohol such as may occur with gasoline.

(3) For air-cooled automobile engines alcohol seems to be especially adapted as a fuel, since the temperature of the engine cylinder may rise much higher before auto-ignition takes place than is possible with gasoline fuel; and if auto-ignition of the alcohol fuel does occur, no injurious hammering can result.

(4) The consumption of fuel in pounds per brake horsepower, whether the fuel is gasoline or alcohol, depends chiefly upon the horsepower at which the engine is being run and upon the setting of the fuel supply valve. It is easily possible for the fuel consumption per horsepower-hour to be increased to double the best value, either by running the engine on a load below its full power or by a poor setting of the fuel supply valve.

(5) These investigations also showed that the fuel consumption was affected by the time of ignition, by the speed, and by the initial compression of the fuel charge. No tests were made to determine the maximum possible change in fuel consumption that could be produced by changing the time of ignition, but when near the best fuel consumption it was shown to be important to have an early ignition. So far as tested the alcohol fuel consumption was better at low than at high speeds. So far as investigated, increasing the initial compression from 70 to 125 lb. produced only a very slight improvement in the consumption of alcohol.

(6) It is probable that for any given engine the fuel consumption is also affected by the quantity and temperature of cooling water used and the nature of the cooling system, by the type of ignition apparatus, by the quantity and quality of lubricating oil, by the temperature and humidity of the atmosphere, and by the initial temperature of the fuel.

(7) It seems probable that all well-constructed engines of the same size will have approximately the same fuel consumption when working under the most advantageous conditions.

(8) With any good small stationary engine as small a fuel consumption as 0.70 lb. of gasoline, or 1.16 lb. of alcohol per brake horse-power-hour may reasonably be expected under favorable conditions. These values correspond to 0.118 and 0.170 gal. respectively, or 0.95 pint of gasoline and 1.36 pints of alcohol. Based on the high calorific values of 21,120 B. t. u. per pound of gasoline and 11,880 per pound of alcohol, these consumptions represent thermal efficiencies of 17.2 per cent. for gasoline and 18.5 per cent. for alcohol.

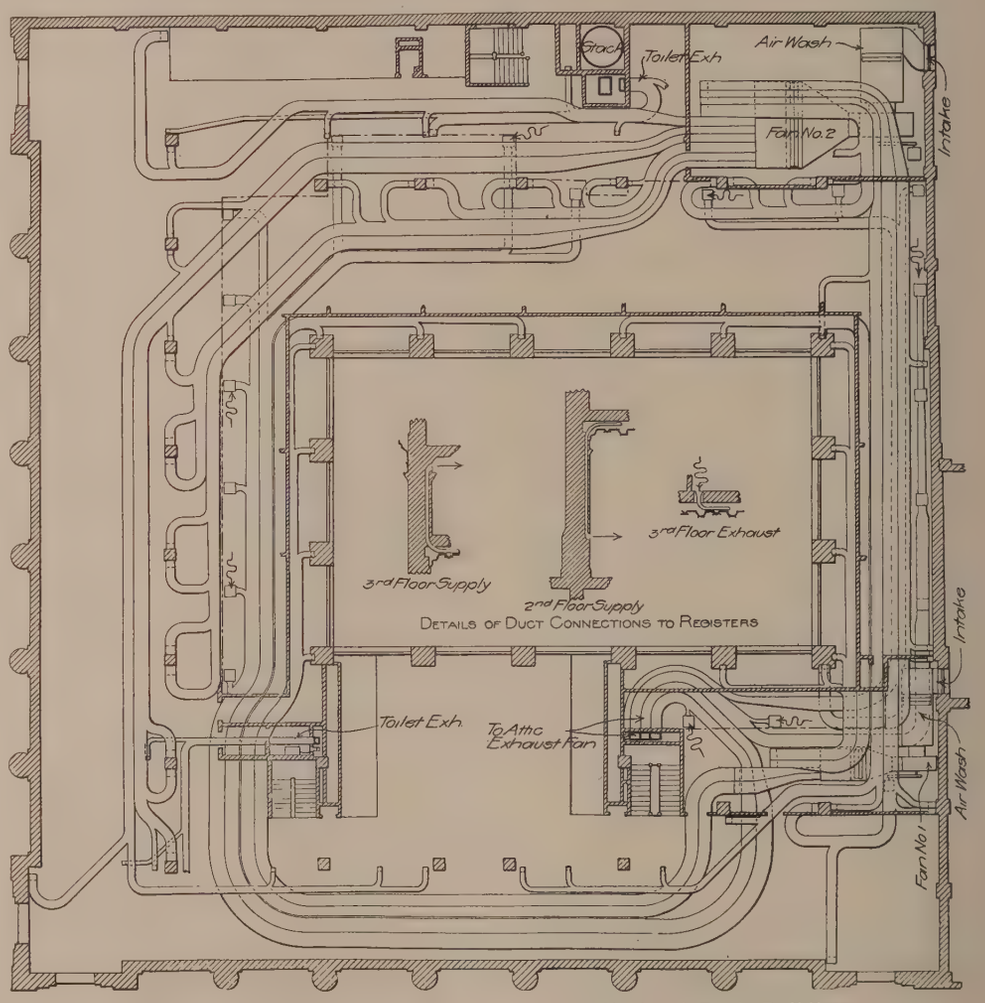
But calculated on the basis of the low calorific values of 19,660 B. t. u. per pound for gasoline and 10,620 for alcohol, the thermal efficiencies become 18.5 for the former fuel and 20.7 for alcohol. The ratio of the high calorific values used above is, gasoline to alcohol, 1.78. The corresponding ratio of the low calorific values is 1.85. The ratio of the consumptions mentioned above is, alcohol to gasoline, 1.66 by weight, or 1.44 by volume.

The High Costs of Operation at Poplar, England, near London, are reported to be the cause of the coming removal to Scotstown, in the Clyde Valley, Scotland, of the large shipbuilding and engineering works of Yarrow & Co.

Heating and Ventilating the Commercial National Bank Building—Part II.

Ventilation.—Mechanical ventilation has been provided for the lower floors of this building to a considerable extent, in addition to the usual exhaust ventilation from toilet rooms, the extensive banking offices and safety deposit department of the Commercial National Bank being fitted for both fresh air supply and exhaust ventilation, while separate ventilating systems are installed for the basement and sub-basement storage and auxiliary rooms, the engine room, the boiler and pump room, and for hot blast in the building entrances in winter weather. For this service seven fresh air supply fan systems have been installed, having an aggregate capacity of 142,330 cu. ft. per minute and three exhaust fans of an aggregate capacity of 41,515 cu. ft. per minute. An interesting feature of the ventilating installation is the use of air-washing systems for all fresh air supplies, except that to the engine and boiler and pump rooms, allowing air intake connections at low levels through the side walls of the building without unpleasant results from the dirt and dust that would otherwise be obtained from this source. Ventilation is effected by admission of fresh air at points in or near the ceilings of the rooms supplied, while foul air is exhausted through registers at or near the floor line, and the air supply is tempered automatically by thermostatic control. Both tempering and reheating coils are used with the supplies having air wash systems and tempering coils only for the two systems fitted with cheese-cloth filters.

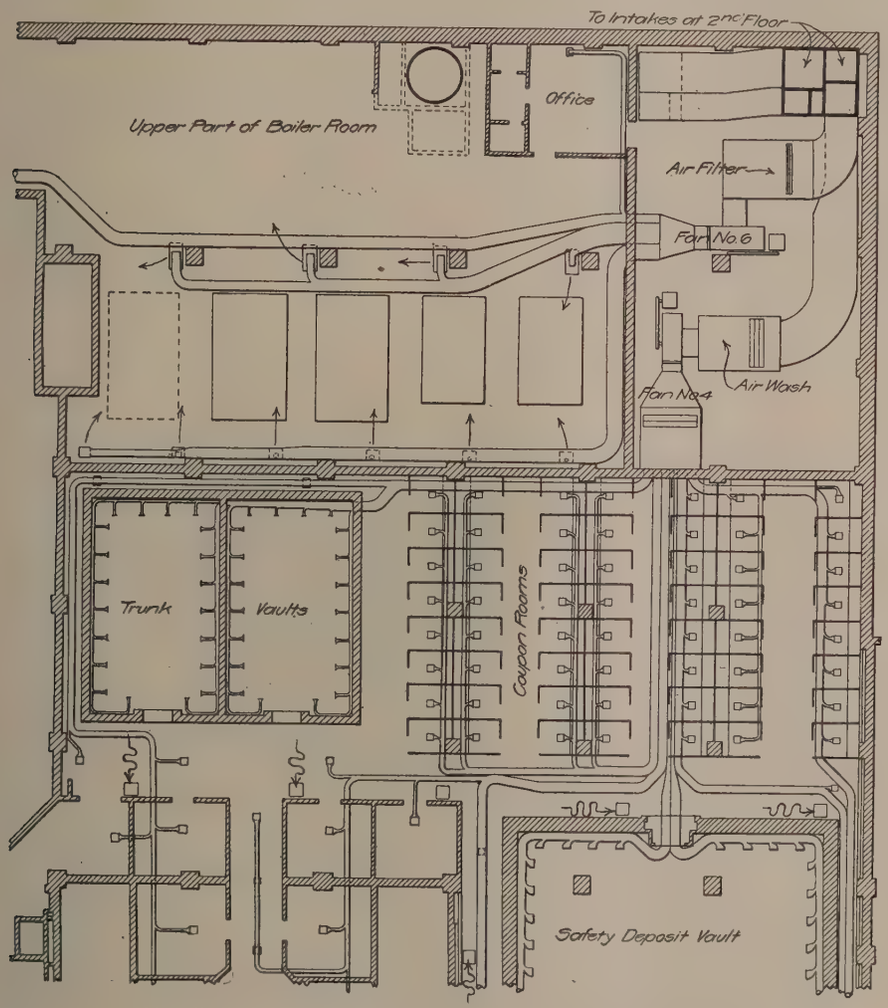
The ventilating services in the different parts of the building are sub-divided and separately operated so that each is entirely independent of



Ventilation of the Bank Division, Commercial National Bank Building.

the other at all times. The banking division which occupies the second floor, the mezzanine and the third floor is supplied with fresh air by two fan equipments, one for the second floor and mezzanine, and the other for the third floor, both of which are located in enclosures at the east side of the third floor convenient to direct intakes through the outside walls to open court spaces. The safety deposit department, which occupies a large portion of the basement, is ventilated by an independent fan equipment located at the northeast corner of the basement with an extensive system of distribution ducts extending principally to the confined spaces and small coupon rooms in the basement, while the street entrances are served by hot blast equipment in the sub-basement for use in winter weather. The retoilet rooms and janitor's closets on all of the upper floors. The use of separate systems, prevents the communication of odors from the mechanical plant or toilets to other parts of the building.

The principal dimensions of the ventilating equipment installed are presented, together with capacities of the fans and of heating coils, in the accompanying table. Each separate system has an extensive amount of distributing duct work, the arrangement of which and the location of outlets are well shown in the accompanying floor plans of the building. System No. 1, supplying the third story of the bank division, delivers air into a corridor surrounding the upper portion of the court space underneath the skylight covering the main bank floor area, delivery



Ventilation of the Safety Deposit Department in Basement.

maining spaces in the basement and sub-basement, such as store rooms, printing office, etc., as well as also the engine room and the boiler and pump rooms have each independent fresh air supply systems, although owing to proximity to steam using machinery, no tempering coils are installed in the fan intakes, and cheese-cloth filters only are used for cleansing the air supply. All exhaust ventilation is operated by fan equipments in the attic, separate systems being installed for exhaust from the safety deposit department, the third story of the bank division, and from the being made through 16 registers on the inner sides of building columns at this level. System No. 2, which is confined to the second story and mezzanine of the bank division, delivers air through four registers to the mezzanine gallery, through 10 outlets in the president's, directors' and other private offices and through 41 openings to the main banking division. The arrangement of these supply registers is such as to thoroughly distribute the air delivered, and these systems were designed to change the air approximately three times per hour in the banking division.

Provisions for exhaust ventilation from this division are made upon the third story level only, in the floor of which there are distributed 18 exhaust registers, 20 in. square, each designed to remove 700 cu. ft. of air per minute; these registers are installed in the outer portions of this floor level where partitions prevent free communication with the large central court space of the main banking division.

In the safety deposit department a somewhat greater proportion of supply is provided for, owing to the more confined spaces ventilated. Here is a safety deposit vault approximately 45 ft. square, to which 1,690 cu. ft. is supplied per minute through 26 register openings, two trunk vaults, 18 x 32 ft. in size each, each of which receives 910 cu. ft. per minute through seven outlets, 56 coupon rooms with separate supplies, which receive in the aggregate over 10,000 ft. of air per minute, and a number of committee and office rooms, which with the main corridor, receive the remaining 3,600 cu. ft. of the supply. The exhaust ventilation provided for from this division is, as will be noticed from the table, somewhat in excess of that for supply, there being a large number of exhaust registers distributed in the floors of the main room, the corridors between the coupon rooms and offices, the committee rooms, offices and toilet rooms. They are so distributed in the relation to the supply register outlet as to effect a positive circulation in all parts. It is to be noted that there are no exhaust vent connections to the vault, circulation being had only at such times of the day when the main vault doors are open. The exhaust fan equipment for this division is, like that for the third floor of the banking division, located in the attic to which duct connections are made through the sub-basement and a 36x42-in. flue extending up the pipe shaft to the attic space alongside of the smoke-stack enclosure. The proportions for supply and exhaust are such as to cause a complete change of air about four times per hour in this department.

Of the remaining systems, that for the main floor entrances was installed solely for the supply of hot blast at the outside entrances in severe winter weather for the purpose of diffusing with the cold air admitted and preventing cold drafts through the corridors. This system is necessarily simple, having a double duct connection to the main entrance to the building from Adams St. and a single duct to the Clark St. entrance. In the Clark St. entrance there are two registers delivering 3,000 cu. ft. per minute, and in the main Adams St. entrance, eight registers having a capacity of 12,000 cu. ft. per minute. These capacities were selected arbitrarily in view of the expected usage of the different entrances and the tempering of the cold drafts admitted thereby. The basement and sub-basement system, No. 5, is the smallest equipment installed, and supplies a printing shop, about 75 ft. sq. in the front corner of the basement with about 3,500 cu. ft. per minute, distributed through ten register outlets, while the remainder goes to a number of store rooms, locker rooms, etc., in the sub-basement, for the employees of the building. The engine room and boiler and pump room systems are each large equipments, intended solely for the supply of cold fresh air to the heated machinery sections and have extensive

VENTILATING EQUIPMENT—COMMERCIAL NATIONAL BANK BUILDING

System.	System No.	Size of Fan, ft.	Wheel Width, in.	Speed. r.p.m.	Capacity, cu. ft. per min.	Motor, H.P.	Heating Coils.—No. of Sections and Lineal ft. of 1-in. Pipe. Tempering.	Heating Coils.—No. of Sections and Lineal ft. of 1-in. Pipe. Reheating.	Air Wash Systems.—No. of Spray Heads.	Air Wash Systems.—Gal. per Min.	Air Wash Systems.—Area, sq. ft.	Pump Motor, H.P.
Bank, 3d story, supply	1	4½	23	306	12,480	7½	3-600	2-600	?	75	32	1½
Bank, 2d story, supply	2	6	40	259	31,745	20	2-1075	4-1200	36	185	76	2½
Street entrances, supply	3	5	23	300	15,000	12½	3-825	3-825	20	125	40	1½
Safety deposit dept., supply	4	5	23	349	17,200	15	3-950	4-325	24	125	39	1½
Basement and sub-base, supply	5	4½	9	344	5,500	5	2-350	2-225	9	75	18	1
Engine room, supply	6	6	35	234	25,750	15	.....	.....	...	...	...	...
Boiler and pump room, supply	7	5½	40	321	34,655	30	.....	.....	...	...	...	...
Safety deposit dept., exhaust	8	5	28	300	18,370	12½	.....	.....	...	...	...	...
Bank, 3d story, exhaust	9	4½	26	267	12,600	7½	.....	.....	...	...	...	...
Toilet rooms, exhaust	10	4	22	332	10,545	7½	.....	.....	...	...	...	...

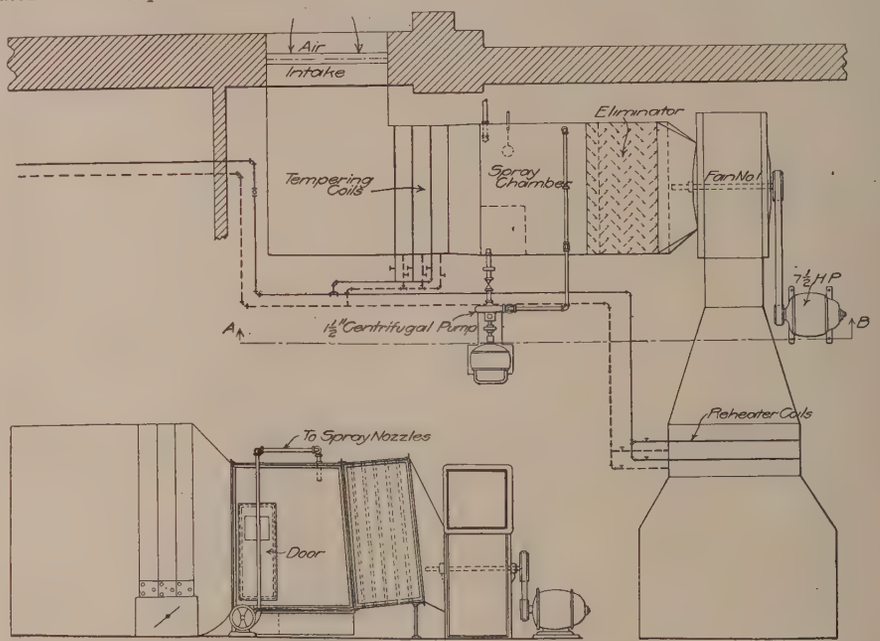
systems of distributing duct work for diffusing the air thoroughly through these rooms. These systems are each proportioned to change the air in the rooms served about ten times per hour for the comfort of the workmen, the outlets being distributed alongside of building columns and along the side walls on either side, as indicated in the plan drawing. A considerable amount of exhaust is effected from these rooms by the boiler furnaces and also by the pipe shaft and enclosure around the steel smoke-stack which rises to a hooded outlet at the roof.

The remaining system, No. 10, serves to exhaust foul air from the toilet rooms on practically all floors of the building. In the lower floors numerous toilet and locker rooms are ventilated from the sub-basement to the second floor mezzanine, above which there is only a janitor's closet and a small men's toilet served on each of the floors, excepting the eleventh story in which the large public toilet rooms of the building are located. For the latter service extensive gathering duct connections are installed, there being an exhaust register located in the rear of each of the toilet enclosures of the extensive groups. This system exhausts about half of its capacity from the toilets below the fourth floor, and over 2,600 ft. per minute from the eleventh floor toilet rooms, while on the other upper office floors, there are uniformly two vent registers to each floor, one exhausting from a janitor's closet and the other from a small men's toilet, and in a number of cases connections to private toilets in special office suites, each of which draws at the rate of 50 cu. ft. per minute.

The fan equipments for these ventilating systems are, as above stated, located in three separate groups, those for the banking division fresh air supply on the east side of the third floor, the remaining fresh air supply fans in the sub-surface floors, and the exhaust equipment in the attic above the eighteenth floor. This arrangement of the fresh air supply apparatus was due in part to the use of the air wash systems which renders the locations independent of consideration as to points of intake of outside air. The two fans on the third floor have intake through ordinary windows opening into open courts at the rear of the building, while those located in the sub-surface floors have intake through ducts carried up to special screened intake openings at the rear corner of the building on the second floor level. In all five equipments fitted with air washing systems, there is in the intake connection a tempering coil for the purpose of preheating the incoming air sufficiently in extreme winter weather to prevent freezing of the spray of the air wash, after which the air is passed to the spray chamber. The air washing apparatus is of the Acme type, furnished by Thomas & Smith, Chicago, which has been previously described in these columns, and consists, in each case, of the spray chamber in which the air passes through an unbroken sheet of water spray and between the latter and the fan intake, a separator or eliminator, for preventing entrained water being carried along in drops into the fan intake. The spray chamber is an enlargement over the intake duct so as to greatly reduce the velocity of the incoming air, and in it are mounted on a pipe framework spray nozzles so placed as to effectively distribute the spray; the nozzles used are the Thomas No. 6 bar lock, circular spoon brass nozzles which are fitted for easily freeing themselves in case they are clogged by obstructions coming through the water piping. The eliminator consists of a series of narrow vertical baffle plates with hooked edges which are so placed as to cause the passing air to take a tortuous path and, as the entire eliminator chamber is inclined slightly upward toward the fan the moisture from the passing air is arrested by the baffle plates and forced downward toward the base of the chamber, where it drains back into the catch basin underneath. The water for the spray is used over and over continuously for a number of days at a time, being recirculated for this purpose by a motor-driven centrifugal pump. The catch basins all have service water supply connections with float valve control to maintain the water level against evaporation by the passing air and all pump suctions have double strainers to prevent obstruction of the piping. The principal details of one of the air washing equipments is shown in the accompanying illustration of the third story system, No. 1.

The fans, which were furnished by the B. F. Sturtevant Co., are of the centrifugal exhauster type with top horizontal discharge casings, and are all belt driven by slow-speed electric motors, operated from the power circuits of the building, which motors were supplied, together with those operating the circulating pumps of the air wash systems, by the Western Electric Co., Chicago. A feature of the duct connections to the fans is the use of canvas boots at the delivery outlets to prevent communication of vibration from the fan casings to the duct work. The boots consist of sleeves of No. 6 duck, 2 ft. in length, well sized and painted, bolted air-tight between the fan outlet and the reheater casing or duct line. The duct work systems are well fitted with dampers, tight closing dampers being installed in all of the intake connections near the outer walls and also for by-passing all heater coils for the purpose of reducing the temperature of the air delivered. At all branches in the duct lines, there are installed adjustable air splits which may be adjusted from outside of the duct to control the amount of air passing in the branches. The duct lines are fitted with cleaning holes, 10 in. square, located at all curves and at all branch connections to main duct lines. The ducts are of galvanized iron construction, heavily braced when greater than 256 sq. in. in cross section and are built of No. 22 gauge metal for lines of 4 sq. ft. area and larger, and of No. 24 gauge for smaller lines. Covering is applied to the duct lines only on the engine room and boiler and pump room systems, and between the intakes and tempering coils of the remaining fresh air supply systems, the covering being of ½-in. asbestos air cell blocks, lapped and canvas covered. The engine room and boiler and pump rooms system filters consist of screens of 1/16-in. mesh wire netting mounted on iron frames over which the cheese-cloth is tightly stretched, each screen being arranged to slide on rollers in independent grooves so that they may be easily removed for cleaning.

The heating stacks installed in all of the fresh air supply systems except those for the engine room and boiler and pump rooms, are of the cast-iron base type, installed in amounts of lineal feet of 1-in. pipe, indicated in the accompanying table, and were furnished by the American Blower Co., Detroit, Mich. Both tempering and reheating coils are installed in from 2 to 4 sections to enable adjustments of the heating surface to be made in accordance with the requirements of the rooms supplied, and all are fitted with by-pass dampers under thermostatic control for securing the desired temperature of delivery. The temperature controlling apparatus for the fresh air supply systems, which together with that for the control of the direct radiation, was supplied by the Johnson Service Co., is especially designed to maintain the temperature of the air delivered at 70° under all conditions. The control is, in the case of the fresh air supply systems, applied to the by-pass dampers underneath the coils while for the direct radiation, thermostats in the rooms controlled operate motor valves on the steam supply connections to the radiators.



Typical Air Washing Equipment, Commercial National Bank Building.

The banking quarters of the building are equipped with a complete system of wiring for call bells, telephones, watchmen's service, telegraph, clocks, etc. A pneumatic tube system for transmission of documents, telegrams, etc., between the various departments was also installed by the Lamson Consolidated Store Service Co. The plumbing and sewerage was installed by M. J. Corboy, and that portion of the drainage below street sewer level is disposed of by a duplicate pneumatic ejector system installed by the Shone Co. Foundations for all machinery were installed by H. A. Bishop & Co., Chicago. The electrical equipment, including generating apparatus, was installed by the Brennan Electric Construction Co., of Chicago, and the elevator equipment by the Otis Elevator Co. The refrigerating plant which is installed for cooling water for the drinking fountains in the hallways is of the absorption type built by the Carbondale Machine Co., Carbondale, Pa. A vacuum sweeping system has also been installed by the Vacuum Cleaner Co.

The ventilating equipment was designed by the architects of the building, D. H. Burnham & Co., of Chicago, under the direction of Mr.

John D. Small, chief mechanical engineer. Thomas & Smith, Chicago, were contractors for the heating and ventilating systems.

A Long Rope Tramway.

A rope tramway 4 km. long and overcoming a difference in elevation of 1,819 m. has been supplied by Ceretti & Tanfani to the Italian military authorities for building a fortress in the Italian Alps. The line starts at Cesana, where the power and loading station is placed. The first section is 1,230 m. long and runs to a station 484 m. above the lower terminal. Between these two stations are several intermediate supporting stations, the maximum distance between them being 400 m. The tramway cable for loaded buckets on this section of the line is a steel rope 24 mm. in diameter, and that for empty buckets is 18 mm. From the second main station there is a span 1,250 m. long, rising 750 m. to the third main station, from which the third section, 1,350 m. long, rises 585 m. higher to the upper terminal station. The tramway cables for the two upper spans are 28 mm. in diameter for the loaded cars and 24 mm. for the empty cars. The cars are hauled by a steel rope 20 mm. in diameter driven at a speed of 1½ to 2 m. per second by hydraulic power. The cars or buckets attached to the hauling rope are spaced 480 m. apart and each of them is rated with a carrying capacity of 400 kg. The tramway is in continuous operation, requiring 55 h.-p. and handles about 144 tons daily. It is stated to have cost about $60,000.

A Freight Movement of 8,630 cars in 24 hrs. is reported as having passed Lewistown Junction on the Pennsylvania R. R. on Sept. 29.

Erecting a Heavy Steel Building with Jinniwinks.

The Boston Elevated Ry. Co. has recently experienced a shortage of power and retained the Stone & Webster Engineering Corporation to investigate their power plants. The report recommended present relief by extensions aggregating about 12,000 kw. for the power stations at Lincoln Wharf, Boston; at Sullivan Square, Charlestown, and at Harvard Square, Cambridge.

The principal power station, at Lincoln Wharf was illustrated and described in The Engineering Record of August 17, 1901. It has a massive steel framework 92 ft. high from foundation line to top of main columns and consists of a one-story engine house 67 ft. 8 in. wide, and a parallel and adjacent boiler house 82 ft. 8 in. wide and three stories in height below the coal bunkers. The engine house has only two longitudinal rows of columns, one of which is on a center line between the two houses and serves for the boiler house also. In the boiler house there are six longitudinal lines of columns, including the one common to the engine house and in the engine house there are only two lines including the same common columns. All of the columns are arranged in transverse bents 17 ft. 7½ in. apart except at the outer end and form three 20-ft. center aisles and two side aisles about 10 ft. and 12 ft. wide in the boiler house and leave a single unobstructed floor space of the full width of the engine house. The coal bunkers 60 ft. wide, extend the full length of the building, and are nearly 60 ft. high from the foundation line to the bottom of the bin. They are made with horizontal transverse bottom girders 20 ft. long and inclined side girders about 35 ft. long over all supporting lines of longitudinal I-beams and tied together at the foot by horizontal eye-bars and at the top by the roof trusses, both passing through the bin. The roof trusses are riveted lattice girders about 6 ft. deep and 60 ft. long for the boiler house and 16 ft. deep and 67 ft. long for the engine house.

Erecting Lincoln Wharf Power House Extension.

In order to increase the boiler capacity it has been found necessary to extend one end of the building with a full width addition occupying a trapezoidal area 150 ft. 4 in. wide by 118 ft. 2 in. long on the long side, and 59 ft. 1½ in. long on the short side, including four regular transverse bents of framework and three special bents at the oblique end. The design was the same as that of the original structure except that it was made somewhat heavier to provide for increased loads, but the erection methods were different and are of interest on account of their simplicity and economy, and of the rapidity and successful results obtained by them.

It was at first intended to erect the new superstructure entirely with overhead movable derricks. Accordingly two steel jinnywink derricks were erected on the roof of the old part of the building and commenced operations by unloading the material from trucks and erecting it complete for the first panel, after which they moved forward on the steel work and erected the next two panels in the same manner.

As the building is situated in a congested part of the city where the street traffic is heavy and cannot be obstructed or interrupted, and as the sidewalk and elevated railroad structures come close to the building lines, it was impracticable to store any materials outside of the building or even to have trucks standing long there while being unloaded. It was therefore necessary to handle the steel work as fast as it was received, and in order to permit the rapid erection demanded by the rush order, it was also necessary to store material in advance of erection inside the building lines.

A guyed steel derrick with an 80-ft. mast and a 70-ft. boom was set up near the middle of the lower floors so as to command practically the entire area of the building and unloaded the bulk of the material. It also erected the columns, beams and girders up to and including the economizer floor on which it stored the material for the upper part of the structure.

Above the economizer floor the structure was erected by the jinniwink derricks moved forward on the completed panels and erecting the members of the framework from the bottom upward exactly as viaducts are erected by overhead travelers. After the completion of the boiler house, a 100-ft., 10-ton steel boom with a special Chicago foot block was set at the foot of one of the intermediate columns in the side wall of the boiler house near the middle of the extension so as to command practically the entire area and height of the engine house, and with it the engine house framework, consisting merely of the one row of wall columns and the roof trusses and connecting members, was erected.

The foot block was made with two 12-in. channels 15 in. long, with their webs 6 in. apart and their flanges turned inwards and riveted to two 12x¾-in. cover plates. The channel webs were punched for four 1-in. horizontal bolts through 12x12-in. horizontal timbers fitted between the projecting edges of the cover plates and forming the cantilever girder anchored to the steel framework of the building and supporting the boom beyond the outer face of the column which was utilized for its derrick mast. The cover plates were bored in the center for a 3-in. vertical pin with a 24-in. grip the upper end of which has a solid collar and engaged a cast-iron knuckle block with eccentric lugs bored to receive the 2½-in. horizontal boom pivot pin.

The jinniwink derrick had steel sills seated

on loose track timbers laid on the upper tier of beams and girders in the boiler house and were readily advanced by pushing forward by hand. The minimum erection gang of six men operating each jinnywink being sufficient for this purpose. The lead lines of their tackles were taken around snatch blocks to the capstan heads of two double-drum American Hoist & Derrick Co.'s engines located on the ground on opposite sides of the building.

The jinniwinks were simply small movable steel derricks of 7 tons capacity, weighing about 3,000 lb. each. The framework consisted essentially of a transverse and a longitudinal horizontal sill forming a T-shape base supporting two inclined shear legs in a vertical plane and one inclined back leg, with a 40-ft. boom pivoted at the intersection of the sills. Most of the members of the framework were made with pairs of 8-in. channels, back to back, latticed, and a second, shorter, transverse sill was attached to the extremity of one of the T-pieces to enable the jinniwink to be moved across open spaces between girders. The length, width and height of the framework were about 20, 12 and 16 ft. respectively.

Neither the guyed derricks or the 100-ft. boom were moved during erection, the latter being arranged to utilize one of the columns of the building for a mast. The field rivets were driven by Chicago Pneumatic hammers operated by air from an Ingersoll-Sergeant compressor. The work was very efficiently executed by a force which, when all six riveting gangs were at work with the erectors, numbered only about 40 men.

The building weighed about 900 tons and the contract for it and for the other two power house extensions was awarded Feb. 15, 1907. It provided that the shipment of steel from the shops must be commenced May 1st, erection commenced May 15th, and the erection of the framework so far advanced that the wall columns should be finished, riveted and painted in readiness for the construction of the wall masonry by July 1st. A bonus was offered for the completion of this work 15 days sooner than contract limit and another and larger bonus was offered for its completion 30 days in advance of contract time. The 30 days bonus was earned with two days to spare for the Lincoln Wharf Power House and with about two weeks to spare for each of the other power houses.

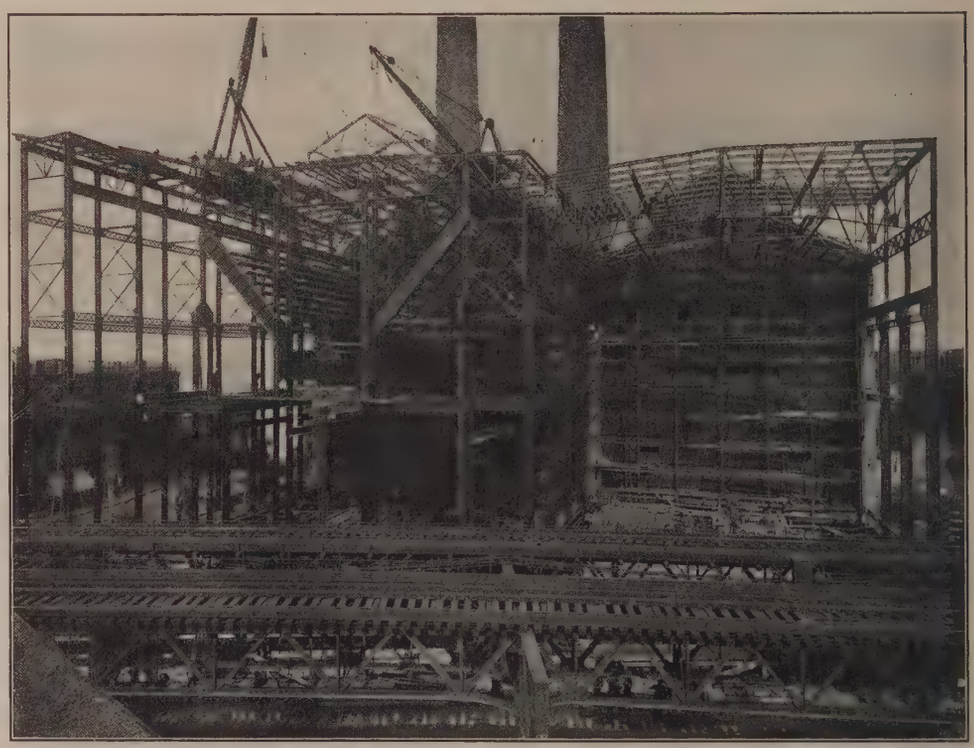
The work was designed and its construction carried on under the direction of the Stone & Webster Engineer Corporation. The contract for the steelwork was awarded to L. F. Shoemaker & Co. The structural steelwork was fabricated at their Schuylkill Bridge Works plant and the erection was directed by Mr. L. D. Rights, contracting manager.

An Automatic Ore-Weighing Machine, said to be the largest yet constructed, has been shipped from England by Messrs. Samuel Denison & Son, Ltd., to the Canadian Northern Ontario Ry. Co., for use at the Parry Sound coal depot of that line. The capacity of the machine is 800 tons per hour. The ore is delivered to a special belt conveyor, 36 in. wide, which travels at a speed of 600 ft. per minute. A continuous weighing apparatus operates in conjunction with the conveyor and a recording indicator shows the total net weight of ore handled in any predetermined period, the tare being deducted automatically. The weighing apparatus operates once every four seconds. The return run of the conveyor belt drives the recording mechanism and controls the weighing, so that slipping on the driving wheel and changes of speed of the belt travel do not affect the accuracy of the results, which, according to "The Engineer," are correct within one-half of one per cent. The English Board of Trade has sanctioned the use of these machines.

The Bracing of Trenches and Tunnels.

The sheathing and bracing of trenches and tunnels in dry and water-bearing materials were treated under the general subject of bracing in a paper on October 16, before the American Society of Civil Engineers. The paper, which was by Mr. J. C. Meem, was entitled, "The Bracing of Trenches and Tunnels, with Practical Formulas for Earth Pressures," and was printed in the Society's "Proceedings," Vol. xxxiii, p. 599. The following abstract gives the main points of the theoretical considerations of the paper.

The term "sheeting" is taken by Mr. Meem to mean that class of sheathing which is set in or driven coincidentally with the excavation. That class of sheathing which is driven ahead of the excavation or beyond its final limits, is referred to as "sheet piling." The general question of earth pressure, in connection with its action on sheeting and bracing, Mr. Meem believes has never been developed so as to reconcile the theoretical with the practical conditions, and he develops a practical basis for effecting an approximate reconciliation between the actual conditions of stability of earth and the theoretical formulas or resultants arising therefrom.



Jinniwink Derricks in Final Position on Boiler House Roof.

In all his experience, Mr. Meem has used the diagram, Fig. 1, for calculations of earth pressure, whether applied to retaining walls or to sheeting and bracing. If *B C* be the line of the sheeting, and *D C* the natural slope of the earth, *b* being the angle of repose, then the mass of earth causing pressure against the line, *B C*, is contained within the triangle, *D B C*. The weight of the earth in this triangle rests on *D C*, and its thrust is transmitted to *B C*, not through the toe of each layer at the foot of its slope line, but by the arching effect of this earth between the lines, *B C* and *D C*. For purposes of calculation, it is probably not far from correct to assume that a line, *A C*, bisecting this triangle, *D C B*, measures with *B C* an area equivalent to the weight transmitted as thrust against this line, *B C*. Also, it is true that the center of pressure against *B C* is where a perpendicular from the center of gravity of the triangle, *A B C*, meets this line.

This assumption is going contrary to the general theory, which assumes that earth pressure acts along the line of rupture and parallel with that line, and is therefore greatest at the toe, but this theory is not borne out in actual practice, and all closely-sheeted, well-braced trenches invariably show a heavier pressure at the top than at the bottom. Any attempt to assume a theoretical condition which is contrary to this fact must be of little value to engineers in making practical calculations. Many retaining walls have been built from designs based on this theory; and Mr. Meem believes that it makes little difference, practically, which form of reasoning is applied to retaining walls. It does, however, make a vast difference which form of reasoning is applied to a braced trench, or to a concrete wall reinforced horizontally; and, while Mr. Meem does not contradict this theory, if based entirely on a theoretical condition of frictionless material, he does advise against its use in ordinary practice.

In other words, if it be assumed that *D C* is a solid plane, and that the triangle, *D C B*, is filled entirely with particles which are absolutely without friction, and therefore the weight of one upon the other transmits accumulatively the weight of all entirely and directly to the bottom, then the truth of the theory noted above cannot be controverted. Such a condition, however, does not exist, and earth pressures and aqueous pressures are not similar; for, in dealing with ordinary materials, it is impossible to proceed with any practical calculations without taking into account the frictional resistance of these materials and their arching effects, which render it virtually impossible to consider their action as in any way allied to hydrostatic action. For instance, Mr. Meem has repeatedly observed where trenches have been sheeted from *B* to *E*. Fig. 1, and the excavation has been continued below *E* without sheeting, that cutting excavations have been made in loams, clays or moist sands back along the line, *E M*, by the use of light poling-boards driven in under the toe of the sheeting at *E*, without disturbing the stability of the mass above. If this sheeting had been so poorly put in as to cause the stability of the mass to be disturbed, it would have manifested itself by the continual dropping of masses of ma-

terial from above, rather than as a constant pressure, as would have been the case had the material been full of water or absolutely frictionless. And, if any small holes should be left between these poling-boards in absolutely dry sand, it would "bleed" in through these orifices just as the sand runs into an hour-glass, until the hole had gone to the top of the excavation, but at no time would there be observed any continuous pressure which could be defined in any way as equal to the entire weight of the sand from the bottom to the top over the unsheeted area.

It may be, as Mr. Meem has frequently observed, that the lower part of a trench may be left unsheeted, as from *E* to *C*, and for a considerable distance longitudinally in clays and moist sands, without disturbing the stability of the face, *E C*, and yet more or less heavy pressure may be observed in the bracing above. This can only be explained on the theory of the arching effect of the material above, one buttress of the arch being *B E*, and the other *D C*. If this be correct, there can be no doubt of the action being wedge-like, with the center of pressure opposite the center of gravity. Any engineer who has had to do with excavations must be aware of the fact that pressures are frequently developed in the top braces and rangers while men are excavating with impunity beyond the limits of

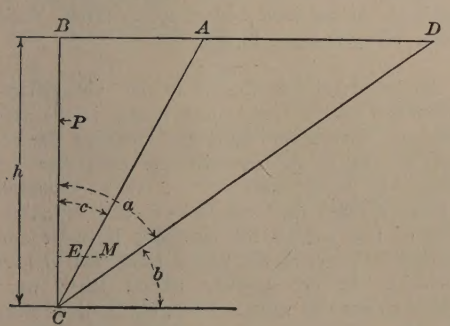


Figure 1.

the sheeting at the bottom of the trench. It is possible, also, at any time to cut or remove the bottom sheeting (except in dry sand) for a considerable percentage of the vertical distance from the bottom, and for indefinite lengths, without interfering with the stability of the bank above, provided the sheeting is removed without jarring. Any practical man, however, will admit that it would be suicidal to remove any one of the braces near the top of the excavation, particularly after the ground had stood for any considerable time.

The practical application of the foregoing will now be shown, and the formula be demonstrated. Let b (in Fig. 1) = the angle of repose, a = 90° − b, c = $a/2$, h = height = $B\ C$, and w = weight of 1 cu. ft. of earth.

Then, the area of $A\ C\ B = h \times h$ tan. $c \div 2$, and the weight of the mass of earth causing pressure on $B\ C = w\ h^2$ tan. $c \div 2$.

The resultant pressure of this mass would occur at two-thirds of the height, or at *P*, in Fig. 1.

In the case of a well-sheeted and braced bank, there would be no overturning moment, but there would be a thrust, represented by the general tendency of the triangle, *A B C*, to slide along the line, *A C*, and therefore move out and exert pressure in a horizontal direction.

To understand this more clearly, it might be well to assume that the lines, *B C A* and *D C A*, are blocks of ice which are held in place along the line, *D C*, by their weight impinging on this line, and on the line, *B C*, by a rigid strut bearing against that line at *P*. If the pressure at *P* be slightly released, the whole triangle, *B D C*, will slide along *D C* and assume a new position. If, again, *A B C* be taken as a solid wedge bearing against a solid block, *A C*, and the wedge be forced down, then, in order that it may be resisted most effectually at any one point, this resistance should be placed at *P*. Or, in a word, Mr. Meem believes that the action of earth pressure in properly braced trenches is more closely allied to that of a coherent solid than to that of an aqueous or frictionless mass.

Mr. Meem believes that there is a limit of depth beyond which it is not possible to brace a trench against the pressures which would be developed, and he believes that this limit could be defined by a simple practical calculation, depending, of course, upon the nature of the soil through which the trench was dug. For example, if a trench be sunk 20 ft. and stopped, the pressure developed at the 15-ft. level will not be excessive, whereas if it be continued to 60 ft. the bracing will have to be heavily reinforced at the same 15-ft. level; and, if the trench be carried down to an indefinite depth, no bracing would eventually be able to withstand the pressures at this same point, owing to what may here be described in a homely way as the "topheaviness" of the bank. Anyone who has had to do with deep trenches or tunnels, however, must realize that an exposed face of earth is under no more

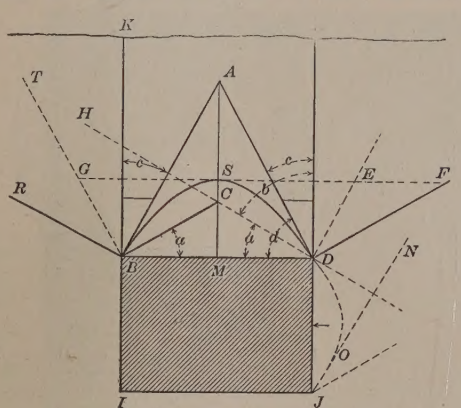


Figure 2.

pressure at the bottom of the deepest trench or tunnel than it is at the bottom of a shallow one.

As an illustration of this several of the bottom plates of a lined tunnel which had been driven at a depth of about 70 ft. by the shield method, were removed, exposing a face of moist sand. The latter was in as quiescent and undisturbed a state as though the exposure had been made only a few feet from the surface.

The danger in sheeting a trench arises mainly from three causes:

a.—In driving the sheeting carelessly and allowing slips to occur behind it; or, in the case of clayey soils, not properly guarding against voids which may occur behind the sheeting. The natural tendency of earth eventually to fill these voids causes slips, which develop not only the full pressures theoretically provided for, but frequently, by reason of the shock incidental to the velocity of slip, cause increased pressure to impinge against the sheeting and incidental bracing.

b.—In not fully tightening the braces by the use of wedges driven practically to refusal; and

c.—Because strata of quicksand may be uncovered in ordinary soil, thereby developing hydrostatic and unbalanced pressures on the sheeting and causing stresses not properly provided for.

There appears to be no controversy as to the generally accepted theory and formula in connection with bracing and sheeting and its relation to earth pressures in subaqueous or other soils so saturated as to be under hydrostatic pressure. If h equals the depth of saturated soil against a sheet pile and w is the weight of 1 cu. ft. of water, then the weight against a pile with a width of 1 ft. would be $w\ h^2 \div 2$, and the overturning moment $w\ h^3 \div 6$, taking the center of pressure at a point one-third above the base.

The next question taken up by Mr. Meem was earth pressures on tunnels or subterranean structures, where it is necessary to consider the other side of the pressure areas noted in the development of the formulas for pressures in open trenches.

Referring to Fig. 2, if it be assumed that *B D J I* is a tunnel (the area of which will be taken as a square, in order to simplify the assumptions), and that *H D* or *D F* is the natural slope of the earth above this tunnel then a = the angle of repose, b = the complement of the angle of repose, and $c = b \div 2$.

As a first assumption, it is unquestioned, of course, that all earth contained in the triangle, *B C D*, necessarily presses directly on the roof of the tunnel. And if the assumptions made at the beginning of this paper are true for open trenches, then it is also true that all the earth contained in the triangle, *A C D*, bears directly upon the line, *C D*, and therefore all this weight likewise is transmitted to the tunnel and all the pressure of the earth in the triangle, *A D L*, goes to the line, *L D*, arching itself somewhere below the triangle, *B A D*, in a curve approximating the line, *B S D*, so that, in a well-braced tunnel, the only pressure on the roof would be that due to the weight of the material below this line. In order to be consistent and carry out the line of reasoning in the original assumption, however, provision must be made for the pressures of all the material in the triangle, *B A D*. No pressure beyond the lines, *B A* and *A D*, can be transmitted to the tunnel unless the ground contains water in such quantities as to make the pressure hydrostatic. Of course, if the tunnel is a subaqueous one, the pressure on the line, *B D*, for purposes of practical calculation, must be that due to the hydrostatic head of the water measured by its depth to the line, *B D*, and by the width of the tunnel opening.

Returning again to earth pressures free from excess of water, it is found, of course, that the larger the angle, a, the greater is the resultant pressure upon the tunnel. It is possible that some may argue from this that the greatest pressure will occur in clayey soil where the earth stands vertically. This supposition, however, is erroneous, because, any soil which will stand vertically and continue to stand vertically under any circumstances must be considered in the same way as solid rock, and cannot be properly classed as material for which bracing is necessary. As a matter of fact, however, clays are treacherous soils for tunneling, and frequently develop pressures by squeezing or sliding horizontally, for which it is difficult to provide.

If, now, it be assumed that the square, *B K L D*, is made up entirely of blocks of ice (or frictionless solids) having an angle of repose of 90 deg., the full weight of this material would have to be provided for in bracing across the tunnel roof, *B D*. If, on the other hand, a material, such as dry sand, be considered, in which the angle of repose is very flat, the arching effect of this material comes more greatly into play by reason of its tendency to slide along the angle of repose, and therefore, the condition of least pressure that can come upon a tunnel in dry ground is where the angle of repose of the superimposed material is least, always providing the material is held by close sheeting. In a word, then, the greater the angle of repose the greater the pressure to be provided for, and this leads to the conclusion that dry sand of a small angle of repose would prove the best material for tunneling if it were possible to sheet and brace the roof absolutely without disturbing its equilibrium. In practice, however, it is, of course, impracticable to drive a tunnel through sand of any kind without having some movement of ma-

terial, and the dryer the sand, the more likely it is to run through any opening in the sheeting.

Here, again, it may be of interest to note that if a frictionless material could be imagined, resting in a trough made by the prolongation of the lines, *R B* and *D F*, measuring the angles of repose, allowance would probably have to be made for the full pressure of the weight of all the material contained within the prolongation of the lines of rupture, *B T* and *D E*. Assuming a case where a tunnel is so close to the surface that the arching effect is lost, for instance, if in Fig. 1 the surface of the ground be taken at *G E F*, it is probable that there would be obtained not only the full pressure of the ground directly above the opening, but an increase due to the lines of rupture, *B T* and *D E*. Therefore, Mr. Meem thinks it is always wise to discontinue tunnel operations when the surface of the ground intersects, or nearly intersects, the perpendicular line, *A M;* and it is within the reasonable limits of good practice to tunnel when the surface of the ground is fairly well above the point, *A*. It may also be of practical interest to note that any longitudinal trenching should always be avoided if possible over the line of a tunnel while it is being excavated owing to the consequent destruction of the key to the arching effect of the ground.

As to the actual pressure: Let l = the width of the tunnel; $A\,M = h = l \times \tan.\ d \div 2$.

Then the area, $B\,A\,D = l\,h \div 2$, and, assuming that $a = 34$ deg., then $c = 28$ deg. and $d = 62$ deg.; and the tangent of d = approximately 2; and l, of course, $= h$.

The area, *B A D*, therefore, becomes $l^2 \div 2$, and $w\,l^2 \div 2$ = the total weight per lineal foot of tunnel, where w = the weight of earth per cubic foot.

As to side pressures, the pressure against the sheeting, *D J*, continues along a line of rupture, *J N*, stopping at some indefinite point, which, for practical purposes, may be taken at *O*, and making the only actual pressure in closely-sheeted work approximately within a line measured by the curve, *D O J*. An excess allowance covering conditions of sheeting, ground, etc., in which judgment is a large factor, should be used in all calculations relating to the question of side bracing, to give a proper factor of safety in connection with this somewhat indeterminate quantity.

As to the question of shaft bracing, Fig. 3 is a cross-section of a square shaft of an area sufficiently small to give the surrounding earth a tendency to arch itself horizontally, it being very probable that such a shaft of reasonably small dimensions and driven as here shown will develop pressures somewhat as indicated by the circumscribed circle. It appears to be reasonably fair to assume that a circular shaft of not too large diameter, driven in dry ground or moist sand, will arch itself so that very little pressure is exerted on the bracing in excess of that originally developed in making the sheeting and bracing tight. This excess pressure is small and indeterminate in actual practice, and may be measured by the intersection of the lines of the arching effect in a horizontal plane and the lines of rupture in a vertical plane, and somewhat as shown in the vertical section in Fig. 3. This pressure varies, of course, in direct proportion to the care with which the sheeting was originally placed. In view of this, it is true, both practically and theoretically, that a small shaft may be driven to any depth without developing any greater pressures below than are found near the surface. As soon, however, as the shaft becomes so large that the horizontal arching effect is destroyed, the action of the pressures becomes the same as the bracing in an open trench, and therefore it would be impracticable to sink to any great depth a shaft the dimensions of which were such as to put it in the same category as trenches.

Mr. Meem showed a photograph of an underpinning pit sunk to a depth of about 18 ft. by the use of horizontal or well-diggers' sheeting. The bottom of this pit is at the level where ground water has been struck, and is there sheeted with interlocking steel sheet piling driven some 5 ft. into the ground to bring its toe well below the sub-grade of the adjoining excavation for which the underpinning is required. This pit can now be pumped out and excavated without danger of bringing in sand, and can then be filled with concrete to form a proper foundation for supporting underpinning timbers. Mr. Meem has personally supervised the work of sinking numbers of similar pits for different purposes, some to depths of 45 ft., without other bracing than the horizontal sheeting noted above, each set alternately bracing the other. It is also known that pits of this character, and not more than 5 ft. square, have been sunk by well-diggers to a much greater depth than those noted without using any bracing other than the sheeting of the character described above.

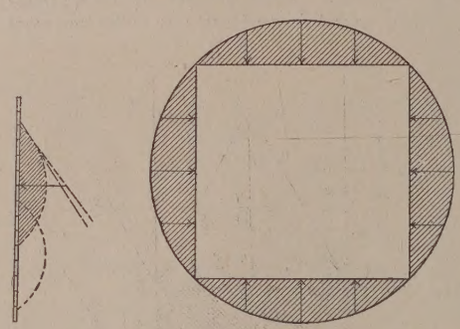


Figure 3.

Mr. Meem believes that the practice of lining circular manholes with masonry walls the thickness of which increases with the depth is not consistent with good designing, and that a circular shaft may be safely designed with a masonry wall which has the same thickness at an indefinite depth as it has near the surface.

The remainder of Mr. Meem's paper illustrated and discussed a few general types and methods of sheeting and bracing, including subway work near the surface and various types of tunnel work.

In closing, Mr. Meem stated that he had written the paper for two main reasons: First, he believes that the subject of bracing and its relation to earth pressures is not properly provided for in the ordinary data and formulas and he hopes, either in this paper or in the resultant discussion, that the question may be established beyond controversy, and on a basis which will be of practical value to engineers and contractors. Second, Mr. Meem believes that insufficient consideration is given to the subject of bracing by engineers in general, it being ordinarily deemed sufficient to leave this question to more or less intelligent foremen; and, while it is not intended to impeach in any way the intelligence of any foreman, it is thought that the subject is one requiring more engineering consideration than is ordinarily given to it.

The Concrete Ties which were placed in the track of the Chicago & Alton R. R., near Lockport, in 1905, are stated to be wearing well, although subject to a heavy traffic. The ties are of the type designed by Mr. G. H. Kimball, of Detroit, and consist of blocks of concrete 3 ft. long, 7 in. high and 9 in. wide. Two of these blocks are connected by a pair of 3-in. channels so as to form a tie of dumb-bell appearance. The rails are carried on top of the concrete blocks by pieces of hardwood, bolted to the concrete and receiving the regular rail spikes.

Book Notes.

A little book which will be helpful to railway surveyors is Messrs. E. F. Hauch and P. D. Rice's "Tables of Quantities for Preliminary Estimates," a title that is a bit misleading, for nearly all the contents relate to a single method of calculating the volume of an embankment. The method followed by the authors is based on a cross-section triangle having for its sides the slopes of the embankment, and for its base the natural transverse slope of the ground. In the tables these slopes are ¼:1, ½:1, ¾:1, 1:1, 1¼:1 and 1½:1. From the area of this triangle was deducted that of the isosceles triangle having for its base the roadbed width, and the remainder was multiplied by 100/27 to give the results in the tables. The tables were checked by a method explained in the book. The roadbeds for which tables are given have widths of 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32 and 35 ft., and for each width and side slope the volume of the section is given for center heights varying by 1 ft. from 1 to 50 ft. There are also tables of toe slopes, cubic yards in 100-ft. sections from the sum of the end areas, decimals of a mile expressed in feet, acreage for a 100-ft. right-of-way, equivalents of chains in feet and feet in decimals of a chain, and fractions of an inch in decimals of an inch and a foot. (New York, John Wiley & Sons, $1,25.)

An important contribution to the published information on industrial disturbances is the volume on "Strikes and Lockouts" forming the report of the U. S. Commissioner of Labor for 1906. It is a book of nearly a thousand pages giving the results of an investigation of this subject for 1901-1905 inclusive and summaries covering the period from 1881 to 1905 inclusive. In the 25-year period there were 36,757 strikes and 1,546 lockouts lasting more than one day. Strikes occurred in 181,407 establishments and lockouts in 18,547, making a total of 199,954 places affected in this way. The number of employes thrown out of work because of strikes was 8,703,824, and the number of those locked out was 825,610, making a total of 9,529,434 people, exclusive of those who were idle on account of shut-downs, which resulted in other industries than those in which these troubles were actually occurring. Of the 36,757 strikes, 69 per cent. were ordered by labor unions, and of the 181,407 establishments involved in strikes, 90 per cent. were included in strikes ordered by labor unions. The average length of a strike was 25.4 days. The employes succeeded in winning all their demands in 48 per cent. of the establishments, partly succeeded in 15 per cent. and failed to win anything in the remaining 37 per cent. Lockouts lasted 84.6 days on an average. They resulted wholly in favor of the employers in 57.2 per cent. of the establishments involved, were partly successful in 10.71 per cent. and failed in 32.09 per cent. The most common cause of strikes was a demand for more wages, which alone was at the bottom of 32 per cent. of these disturbances and was a partial cause of about 8 per cent. more. The cause next in importance was a demand for recognition of unions and union rules. Over half of the lockouts were caused by a refusal to recognize union demands. Over a quarter of all the strikes and over a third of all the establishments they affected were in the building trades. About 25 per cent. of the strikers were in Pennsylvania, 21 per cent. in New York, 13 per cent. in Illinois, 6 per cent. in Ohio, and 5 per cent. in Massachusetts. The volume contains a great mass of statistics on the subject, and also a large amount of information regarding strikes and lockouts in other countries. (Washington, Department of Commerce and Labor.)

The fifth edition of Mr. Edward Wegmann's "Design and Construction of Dams" has been thoroughly revised so that the new theories of the design of masonry dams and the many important recent structures of both standard and novel character are explained. This edition contains 93 more pages, 39 more plates and 45 more figures than appeared in the edition of 1904, and a considerable part of these additions give information not readily found elsewhere. The book has been regarded for so many years as one of the standard American engineering treatises that it is hardly necessary to give any long review of its contents, which cover all types of fixed and movable structures for impounding water. (New York, John Wiley & Sons, $6.00.)

Letters to the Editor.

ROCK TUNNELING MACHINES.

SIR: In the number of your paper for Oct. 19 I was very much interested in the article on the machine for tunneling in shale. I send you a photograph of a small section of the tunnel which the machine bored before it was removed. The total distance bored was about 2 ft. We all regretted very much the failure of the machine to carry out the work.

Yours truly, H.

A REINFORCED TILE WALL.

SIR: As bearing on the note in your paper of Oct. 12 concerning reinforced brickwork, I would call your attention to a test of a partition wall in the Criminal Court Building, Berlin, designed by me while chief engineer of the Lolat Concrete-Steel Construction Co. of that city. The belief that brickwork containing steel reinforcement was about as "monolithic" as reinforced concrete led me to propose such material about four years for some 170,000 sq. ft. of partitions. The wall built for a test consisted of two thin walls of porous brick or tile. Running lengthwise of the wall at four of the longitudinal joints were ⅜-in. rods, two rods being used to each of the three upper sets of reinforcement and four in the bottom set, which was in a joint close to the floor. The wall was tested by laying transverse I-beams across the top and suspending a platform from their ends on each side, and then loading the platforms. This wall was one of seven submitted in competition, and although it contained the smallest amount of steel it had the highest test load. In fact, it was impossible to cause any cracks or marked deflection by any load that could be applied.

Yours very truly,

O. GOTTSCHALK.

CHICAGO, Oct. 18.

RESTRICTING COMPETITION ON LOCAL WORK.

SIR: From investigations of the past records of public work, we are of the opinion that proposals for public work are not advertised in over 20 per cent. of the work let. The lack of this publicity causes little, if any, competition, and it permits a few local contractors to take work at high figures, and also permits illegal combinations between a few local contractors, resulting in the pooling of bids at the city's expense. In our work in something over 130 municipal plants, we have always adhered to the policy of advertising the work in some engineering and contracting papers. An investigation of Oklahoma and Indian Territory records show twelve waterworks plants installed in the last year, none of which were advertised except in the home paper, the work going to a combination of two or three contractors whose engineer withholds the publicity of the letting.

We are writing to suggest the advisability of a certain movement on the part of engineering and contracting papers to attempt to get legislation in the different States, compelling the advertisement of public work in engineering and contracting papers. This could especially well be taken up with the new State of Oklahoma, where laws will soon be made pertaining to public work. We believe, however, that similar legislation could be recommended and passed with slight opposition, and perhaps no opposition, for representatives from the cities would realize at once that this would result in saving much to the cities.

Knowing that you are interested in this matter, we would be pleased to receive your ideas and any suggestions you may have along this line.

Very truly yours,

BURNS & MCDONNELL.

KANSAS CITY, Oct. 22.

[The opinions of The Engineering Record on this subject have been stated at considerable length on several occasions, the last time on July 4, 1903. Assuming that a failure to advertise proposed work in journals of wide circulation is due only to a desire to restrict competition to local contractors, which is generally the case, it follows that such a plan simply results in throwing large contracts into the hands of people without resources for handling them. Local contractors of experience and business standing can underbid outside contractors on works up to the limit of their resources, and it is noteworthy that where large works must be done and outside firms are given the contracts they generally engage local sub-contractors and workmen and buy their supplies locally so far as practicable. It is far better for a community to advertise all large works and thus have them constructed by a company of experience and financial resources than to let the works to local parties who do not know how to carry them on and do not have the financial standing necessary to handle such extensive operations. Letting such works to local parties without outside competition is simply giving them a business education at the expense of the taxpayers without any good resulting to the city or citizens.—Editor.]

Cut by Tunneling Machine.

THE IMPORTANCE OF STEFFAN AND BOLTZMANN'S RADIATION LAW.

SIR: In a forthcoming bulletin entitled "Study of Four Hundred Boiler Tests, with Deductions," the Steam Engineering Division of the United States Geological Survey treats of the lately developed and proven law of Steffan and Boltzmann regarding the total radiation of heat (including light) from a hot to a cold body.

It was formerly thought that the amount of heat radiated was proportional to the temperature difference. Inasmuch as former experimental work was done at low temperatures the error of this assumption was very small. But of late years, since interest has arisen in the quantitative investigation of high temperature furnaces, it has become important to think with the true law in mind. This law of Steffan and Boltzmann states that if two infinite plane surfaces are close together, or, better yet, if a ball is inside a hollow sphere, all surfaces being in all cases of the same material, in the same state of surface finish—this law states that the rate of heat radiation from the hotter to the cooler surface is:

Rate of radiation $= K\ (T_1^4 - T_2^4)$.

Where K = a constant for any particular set of bodies and surfaces T_1 = the absolute temperature of the hotter body, T_2 = the absolute temperature of the colder body.

The above equation is equivalent to stating that each body radiates heat and receives heat by radiation; that the rate of radiation from each body is proportional to the fourth power of its absolute temperature; and therefore that the net amount of heat given up by the hotter body to the cooler one is proportional to the difference of the fourth powers of their absolute temperatures.

The above mentioned forthcoming bulletin giving a "Study of Four Hundred Boiler Tests, with Deductions," makes a number of applications of this law. Some similar applications are given below.

In a Heine water-tube boiler having the lower row of tubes over the furnace completely encased in clay tiles, excepting about 3 ft. at the rear end, over the combustion chamber, this exposed 3 ft. of tubes absorbs heat not only from convectional contact with the gases entering the boiler, but also from intense radiation from the white-hot combustion chamber walls and bottom.

The soot covering of the water tubes is of a different surface and finish from the surface of brick and slag constituting the combustion chamber walls and bottom; nevertheless the above equation will hold approximately, and a couple of examples are given to show the enormous increase of this radiation factor with rise of combustion-chamber temperature.

Example 1.—Let the soot on the exterior of the water tubes have an average temperature of 1239° F.—a dull red heat. Adding 461° F. to get the absolute temperature, we have $T_2 = 1700°$.

Assume the rear furnace temperature to be 2039° F., a rather poor condition of operation. Adding 461° to 2039° we have $T_1 = 2500$. Then, net heat received by tubes per second from furnace bottom and sides $= K\ (T_1^4 - T_2^4) = K\ (2500^4 - 1700^4) = K\ (30{,}710{,}400{,}000{,}000)$.

Example 2.—Let the average soot temperature be 1239° F. or 1700° F. absolute as before.

Then $T_2 = 1700°$. Assume that the average rear combustion-chamber temperature is only 500° higher than in Example 1; that is, 2539° F., a medium temperature; then $T_1 = 3000°$.

Then, net heat received by tubes per second from furnace bottom and sides $= K\ (3000^4 - 1700^4) = K\ (72{,}647{,}900{,}000{,}000)$.

Example 3.—Assume as before $T_2 = 1700°$ absolute and raise the furnace temperature another 500° F. to 3039°, which would be wall tempera-

ture in quite a hot furnace. Therefore, $T_1 = 3500°$.

Then, net heat received by tubes, etc. $= K (3500^4 - 1700^4) = K (141,710,400,000,000)$.

SUMMARY OF EXAMPLES.

Dropping the constant K and the last twelve figures of every answer, we have,

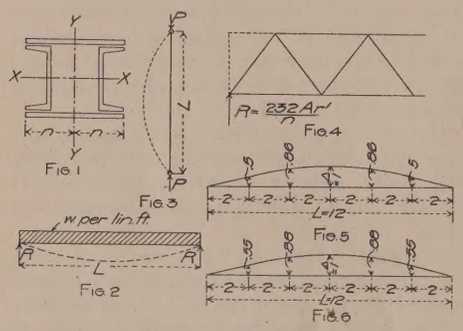
Furnace Temp.	Tube Temp.	Number to Which Net Radiation is Proportional.
2039° Fahr.	1239° Fahr.	31
2539	1239	73
3039	1239	142

The heat absorbed from radiation practically doubles with every 500° increase in combustion-chamber temperature.

As a matter of fact the temperature of the soot on the tubes rises a little as the furnace-wall temperature rises, and it is also a better radiator of heat than is the brick wall. Nevertheless the above examples are substantially correct.

The above calculations give no idea as to whether the percentage of heat received by a boiler from radiation is the larger or smaller portion of the whole. In the "Study" mentioned some numerical calculations are given, determined by two independent methods of approach. The results are probably right within 20 per cent.

It is evident, in the case of an ordinary multitubular boiler burning smokeless coal right under the boiler shell, that perhaps half of the heat enters the water from a radiation source. Even in water-tube boilers it may be about 20 per cent.



Lattice-Bar Diagrams.

In locomotive boilers the firebox may sometimes absorb perhaps 30 to 50 per cent. of the total heat absorbed, most of this 30 to 50 per cent. being due to radiation.

The engineers of the Steam Engineering Division were recently much surprised at the magnitude of thermometric errors due to radiation when measuring the temperature of dry gases. If the bulb of a thermometer have a chance to "look out-doors" when in a hot chamber surrounded by a flowing stream of hot gas, it may read twenty or thirty degrees low at the moderate temperatures of 500 or 600° F.; nor does the "window" have to constitute a very large percentage of the chamber walls in which the bulb is situated. Two thermometers a little over an inch apart in the same long chamber, swept by the same stream of hot air, were found to read nearly 100° apart; a third one farther along, carefully closed in, read nearly as high as the first one. All the instruments were carefully calibrated and were repeatedly interchanged.

In superheated steam work such errors are very persistent. It is no easy matter to get the temperature of a flowing stream of superheated steam within 10° of the true temperature. It may be said that under such circumstances the thermometer bulbs are always colder than the steam; the only question is, how much? This fact alone will explain away many troubles engineers have had in working with superheated steam and other permanent gases.

In determining the temperature of flue gases in boiler practice the errors due to radiation of heat from the thermometer bulb are usually large. Unless the bulb is carefully protected from radiation by two or three concentric chambers around it, it is likely to read dozens of degrees low. A moment's reflection will make it evident that all surface ordinarily "visible" to the thermometer bulb is hundreds of degrees colder than the gases (and than the bulb). This is true of the brickwork, the adjacent water tubes and steam drums, the stack and the sky above.

The measurement of the temperature of a permanent gas is a high art.

Walter T. Ray.

Diagram for Reinforced Concrete Beams.

Sir: In your issue of July 27 of this year you published an abstract of the report of the British Joint Committee on Reinforced Concrete, containing certain formulas recommended by that Committee for use in proportioning reinforced concrete structures. I am sending you herewith a diagram showing certain relations in those formulas, which may be of some interest to your readers.

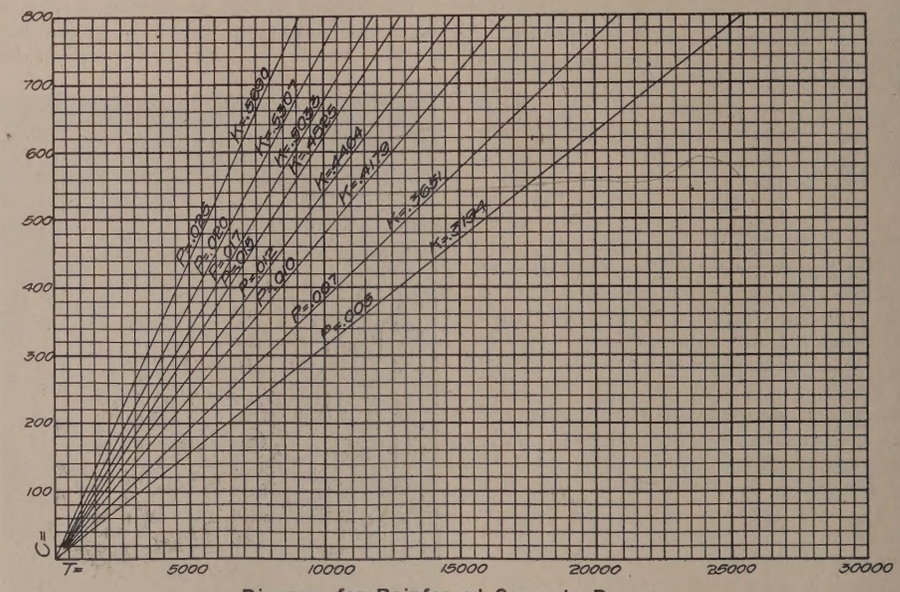


Diagram for Reinforced Concrete Beams.

In this diagram C is the compression in the extreme fiber of the beam, expressed in pounds per square inch; T is the tensile stress in the steel, expressed in pounds per square inch; P is the ratio of the area of steel to the area of concrete, and K is the ratio of the distance of the neutral axis below the extreme upper fiber to the distance of the center of gravity of the steel below the extreme upper fiber. The ratio of the coefficient of elasticity of steel to the coefficient of elasticity of concrete is assumed to be 15.

Yours very truly,

Geo. T. Prince.

A Formula for Lattice Bars.

Sir: In your issue of October 12, Mr. Henry S. Prichard has a letter on stresses in the lattice bars of columns. I send herewith some notes on a formula that will give, I think, approximate results.

Let L be the length of the column in feet, A the area of its section, Q the section modulus for the axis $Y\ Y$ in Fig. 1, r the least radius of gyration in inches, l the length of the column in inches, w the load per linear foot of the column as explained below, r' the radius of gyration for the axis $Y\ Y$ in Fig. 1, and n the distance of the extreme fiber from the axis $Y\ Y$.

The New York law gives the following formula for the pressure in pounds per square inch, $15,200 - 58\ l/r$, or if l is in feet, $15,200 - 696\ L/r$. If L is very short then we can use 15,200 lb. per square inch, and under this assumption evidently $696\ L/r$ may be taken as the stress per square inch due to bending in the column. Calling this stress S',

$$S' = 696\ L/r'.$$

If the column is put in a horizontal position and a load w per linear foot is applied, it would tend to take the shape shown by the dotted line in Fig. 2. If the column is pin-connected top and bottom and a load P is applied, it will take the shape shown by the dotted line in Fig. 3, or approximately the same curve shown in Fig. 2. Therefore we may assume that the bending in the column is the same as would be caused by an evenly distributed load as shown in Fig. 2. Then $w\ L^2/8$ is the bending moment in foot-pounds, or

$$12\ w\ L^2/8 = \text{Bending moment in in.-lb.}$$

But $m/Q = S''$

where S'' is the stress per square inch due to bending.

Hence $12\ w\ L^2/8\ Q = S''$. But $Q = Ar'^2/n$ and therefore $S'' = 12\ wl^2/8\ Q \times n/Ar'^2 = 3\ wL^2n/Ar'^2$. But $S' = S''$, therefore $696\ L/r' = 3wL^2n/2Ar'^2$ and $w = 464\ Ar'/Ln$. Hence R in Fig. 2 is found from the expression $R = 464\ Ar'/Ln \times L/2$, and $R = 232\ Ar'/n$.

Having found the end reaction R it is easy to find the stress in a lattice bar by treating it the same as a lattice truss, see Fig. 4. If the column is fixed at both ends, the bending moment will be $wL^2/12$, which gives

$$R = 348\ Ar'/n.$$

A comparison of the two curves in Figs. 2 and 3 may now be made.

The curve shown in Fig. 3 is a sinusoid whose equation is $y = \Delta \sin n\ \pi\ (x/L)$. (See Merriman's "Mechanics of Materials," 1894 edition, p. 115). In the case considered $n = 1$, and if we assume $\Delta = 1$, the equation reduces to $y = \sin \pi\ (x/L)$. If we plot this curve, using 12 for L, we get the coordinates shown in Fig. 5.

Referring now to Fig. 2, we have a parabola, and if we plot this curve we get the coordinates shown in Fig. 6.

By comparing Figs. 5 and 6, we see that they are approximately the same. When Δ is very small, which is the case in columns, we can therefore safely say the two curves are alike.

Yours truly,

W. W. Pearse.

New York, Oct. 19.